1994

Winter Diet and Nutritional Condition of White-Tailed Deer in the Northern Black Hills, South Dakota

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WINTER DIET AND NUTRITIONAL CONDITION OF WHITE-TAILED DEER IN THE NORTHERN BLACK HILLS, SOUTH DAKOTA

By

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A thesis submitted in partial fulfillment

of the requirements for the degree

Master of Science

South Dakota State University

1994

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusion of the major department.

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ACKNOWLEDGEMENTS

I thank my advisor Jonathan A. Jenks for his advice, encouragement, and most importantly his patience for the duration of this project. Les Flake, Gary Larson, and David Evans served on my advisory committee and reviewed this thesis; their comments and suggestions were appreciated.

I wish to express my gratitude to Steve Griffin and Mick Muck, who contributed a great deal of time and effort towards the successful completion of this project. McNenney State Fish Hatchery allowed me access to their laboratory and equipment. Special appreciation is extended to Will Sayler for his assistance and friendship. Jill Rieck and the Spearfish district of the Black Hills National Forest provided advise and support throughout this study. Shaun Grassel and Mark Ferdig provided technical assistance with various portions of the lab work.

I would like to thank Gladys Nicholas who provided housing and guidance; her knowledge of Spearfish and the surrounding vicinity were indispensable. Charles and Sallie Nicholas provided extensive assistance; this project would have been much more difficult without their help. Many landowners in the northern Black Hills graciously allowed me access to their land; without their cooperation this study would not have been possible.

I would also like to thank my parents, Jim and Marilyn Osborn. Their continual support and encouragement have made this possible.

This study was supported by South Dakota Department of Game, Fish and Parks and Pittman-Robertson funds (Project W-75-R-7558, Federal Aid to Wildlife Restoration Fund).

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ABSTRACT

Robert G. Osborn

Habitat deterioration in the northern Black Hills (NBH) of South Dakota may be responsible for declining white-tailed deer (Odocoileus virginianus) population levels (Griffin et al. 1992). Because of the relationship between habitat and nutrition, a two-year research project was initiated in January 1992 to evaluate the physical and nutritional condition of white-tailed deer inhabiting five NBH winter subranges. Habitat variables were measured at 100 random locations on each study area. Pellet groups were collected throughout each study area at two-week intervals during January, February, and March 1992 and 1993. Five female white-tailed deer were collected from each study area in February 1992 and 1993. Diet quality was monitored using fecal nitrogen and phosphorus levels. Diet composition was evaluated using microhistological analysis of fecal samples. Eight blood and 10 morphological/physiological indices were used to evaluate deer condition. Using principal component analysis, winter subranges were separated into two categories: 1) ponderosa pine dominated, forested areas and 2) agricultural areas. In the mild winter of 1992, fecal nitrogen and phosphorus levels indicated that deer were consuming a spring diet by

late March. In 1993, diet quality did not differ intraseasonally but fluctuated with snow levels. Intraseasonal trends in dietary composition paralleled changes in diet quality. Diet composition gradually changed from a winter diet to a spring diet in 1992 and fluctuated with snow depth in 1993. Despite higher animal densities, fecal nitrogen and phosphorus levels indicated supplementally fed deer consumed higher quality diets than non-supplemented animals in 1992 and 1993. Higher quality diets among supplemented animals may be related to higher corn consumption during both years and lower consumption of ponderosa pine (Pinus ponderosa), juniper (Juniperus spp.), and shrubs in 1993. Across all but one non-supplemented subrange, consumption of Oregon grape (Berberis repens), a low growing nondiciduous shrub, declined in the more severe winter of 1993, while consumption of other shrubs increased in 1993. Deeper, more persistent snow resulted in poorer deer condition in 1993. Total serum protein and fat indices declined from 1992 to 1993, indicating lower protein and energy availability in 1993. Although non-supplemented winter subranges were able to meet deer nutritional requirements during a mild winter, deer relied more heavily on body reserves in 1993. Supplemental feeding improved diet quality and deer condition. Alternatives to improve deer condition include population reduction and winter range improvement.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

Figure Page

LIST OF APPENDICES

Chapter 1

Introduction

The nutritional status of wintering white-tailed deer (Odocoileus virginianus) is partially a reflection of winter range quality. Winter range has been studied intensively in northern latitudes because most natural deaths of adult deer occur during this season (Mautz 1978a). Habitat quality is a function of the distribution, quality and availability of deer forages (Hobbs and Swift 1985, Hanley and Rodgers 1989). Condition indices have been used to assess population health. Blood indices (Seal et al. 1972, Franzmann and LeResche 1978, Jenks et al. 1991) and morphological/physiological indices (Verme 1963, Finger et al. 1981, Kie et al. 1983) have been used in monitoring physical and nutritional status of wild ruminants.

Microhistological fecal analysis has become a popular method of food habit analysis since it was introduced by Baumgartner and Martin (1939) for analysis of fox squirrel (Sciurus niger) diets. The method also has been successfully used for deer (Anthony and Smith 1974), elk (Cervus elaphus) (Leslie et al. 1984), cattle, goats, and sheep (Alipayo 1992), and African herbivores (Arman et al. 1975). However, winter deaths usually result from chronic undernutrition rather than starvation (DelGiudice and Seal 1988).

Indices such as fecal nitrogen and phosphorus have been correlated with dietary nitrogen and phosphorus

intake, respectively, for black-tailed deer (O. hemionus columbianus) (Leslie and Starkey 1985) and white-tailed deer (Howery and Pfister 1990) and have been used to monitor diet quality. Use of fecal indices can provide information on recent nutritional history, which may reflect variation in habitat quality (Dinkines et al. 1991).

To be meaningful, data used to calculate condition indices should be collected concurrently with environmental, habitat, and nutritional information, and if possible, compared to baseline data for the particular population in question. Unfortunately, little baseline data concerning deer condition or diet quality is available for Black Hills deer and few studies have attempted to tie physical and nutritional condition to dietary or habitat characteristics. As a result, baseline values are unavailable for the northern Black Hills (NBH) and interpretation of existing data is difficult. The primary objective of this study was to evaluate physiological and nutritional condition of white-tailed deer inhabiting five NBH winter subranges to establish baseline information and determine those physiological and morphological indices related to dietary and habitat characteristics.

The study had four objectives, 1) to assess habitat variation among subranges, 2) to determine winter diet quality of white-tailed deer, 3) to determine winter diet

composition of white-tailed deer, and 4) to determine white-tailed deer nutritional condition in winter and summer. Simultaneously evaluating habitat characteristics, diet quality, diet composition, and deer condition may reveal important dietary and/or habitat components necessary for maintaining a healthy and productive deer population in winter.

Chapter 2

Habitat Variation Among Winter Subranges in the Northern Black Hills, South Dakota

INTRODUCTION

The nutritional status of wintering white-tailed deer (Odocoileus virginianus) is partially a reflection of winter range quality. Winter range has been studied intensively in northern latitudes because most natural deaths of adult deer occur during this season (Mautz 1978a). Even during a moderate winter, food available to deer generally provides only a subsistence diet (Harris 1945). Habitat quality is a function of the distribution, quality and availability of deer forages (Hobbs and Swift 1985, Hanley and Rodgers 1989). Topography (Hobbs 1989), canopy cover (Crawford 1984), aspect (Pase 1958), and other habitat variables can influence accessibility of winter forages.

White-tailed deer in the northern Black Hills (NBH) show a high fidelity to winter subranges (Kennedy 1992). Furthermore, winter subranges are disjunct topographically; subranges are separated by ridges and deep gulches that make interrange travel energetically expensive for deer. As a result, it is possible to examine winter diet, along with physical and nutritional status of deer associated with a specific subrange. The purpose of this study was to characterize five winter subranges used by deer in the NBH, using habitat variables. I hypothesized that habitat characteristics would not differ among winter subranges.

STUDY AREA

The study was conducted in the northern Black Hills (NBH) of South Dakota. Climate in the northern Black Hills is continental (Thilenius 1972). During 1951-1974, temperature extremes were -34.4 and 41.1°C (Meland 1979). Average total annual precipitation around Spearfish is 50.8 cm (Thilenius 1972, Severson and Thilenius 1976, Meland 1979). May and June are the wettest months (Severson and Thilenius 1976) with 70% of precipitation occurring April through September (Meland 1979).

Black Hills forests are dominated by ponderosa pine (Pinus ponderosa) (Severson and Thilenius 1976). As elevation within ponderosa forests increases, understory becomes more diverse. A transition zone from ponderosa pine forests to aspen (Populus tremuloides) and white spruce (Picea glauca) forests exists from 2,000 to 2,100 m above mean sea level. Above this elevation, aspen and spruce forests dominate (Hoffmann and Alexander 1987). Common deciduous forest types, in addition to aspen, that occur in the Black Hills are paper birch (Betula papyrifera) and bur oak (Quercus macrocarpa) (Severson and Thilenius 1976). Schneeweis et al. (1972) and Thilenius (1972) observed that although the number of overstory species is limited, the understory is enriched with grasses, forbs, and shrubs.

The three dominant soil types that are found in the northern Black Hills are Paunsaugunt-Rock outcrop, Nevee-Vale-Tilford, and Barnum-Swint-St. Onge (Meland 1979). Paunsaugunt-Rock outcrop, the most common, is found on uplands and is a shallow, well to somewhat excessively drained soil found on moderate to steep slopes and rock outcrop. Nevee-Vale-Tilford is a deep, well-drained, silty upland soil. Barnum-Swint-St. Onge is a deep, well drained, loamy to silty soil found on bottom lands and terraces.

Five study sites (Fig. 1) totaling 1744 ha were located westward from Spearfish, South Dakota, to the Wyoming border. Study sites (subranges) were delineated from locations of radio-collared deer (Kennedy 1992). All five are approximately located at 44° 30′ W latitude and range in longitude from 103° 50′ N to 104° 04′ N. Study areas (i.e., Badger [B], Burke/Larson [BL], Crow Creek [CC], Bear Ridge [BR], and Sleep/Nicholas [SN]) consist of a mixture of federal, state, and private land.

Across all sites, about 18% of land was located within the boundary of the Black Hills National Forest, Spearfish Ranger District. Livestock grazing, timber production, and recreation are the principal land uses (Kennedy 1992). The Badger study area partially included a State-owned Game Production Area. Game production areas in this vicinity are managed to reduce deer, elk (Cervus elaphus), and

turkey (Meleagris gallapavo) depredation on neighboring private land. The South Dakota Department of Game, Fish, and Parks has established food plots and provides supplemental feed during winter. Private lands are predominantly used for ranching and agriculture. Alfalfa (Medicago sativa), winter wheat (Triticum aestivum) and oats (Avena fatua) are the primary crops (Kennedy 1992). Pasture mixtures containing alfalfa, sweetclover (Melilotus spp.), intermediate wheatgrass (Agropyron intermedium), western wheatgrass (A. smithii), and orchardgrass (Dactylis glomerata) also have been planted.

METHODS

Field Methods

Deer density was determined from track counts (Mitchell 1986). Two transects were established on each study area originating from a random location, and running for 0.81 km (0.5 mile) in a randomly determined compass bearing.

Habitat characteristics were recorded at 100 (50 annually), randomly determined locations on each subrange (500 total observations). Topographic maps (scale=1:24,000) and Universal Transverse Mercator (UTM) grid coordinates (Grubb and Eakle 1988) were used to locate the random sites. The random point designated the center of a 500-m^2 (20 m by 25 m) plot from which habitat data were collected.

General site information included elevation and percent slope (Kennedy 1992). Additionally, the distance to the closest road, edge (any break in habitat type), water source, and active logging site (if any) was noted (Kennedy 1992). Within the 500-m^2 plot, the dominant overstory tree species along with associated understory vegetation were recorded. Pine and aspen habitats were classified according to guidelines established by Hoffmann and Alexander (1987) and Severson and Thilenius (1976), respectively. From plot center, tree basal area of each overstory species was measured using a 10 factor angle gauge (Hovind and Reick 1970). Diameter at breast height (dbh) for each tree included in the basal area count was measured to the nearest cm using a diameter tape. Canopy cover was measured with a spherical densiometer at plot center.

Ground cover (defined as $\leq$1 m in height) was systematically sampled within the 500-m^2 plot. Three parallel, 25 m transects were established within the 500-m^2 plot at 10 m intervals. Five, 1-m^2 (1 m by 1 m) quadrats were located along each transect at 5 m intervals (for a total of 15 quadrats per 500-m^2 plot) (Kennedy 1992). Ground cover was assessed using Daubenmire cover classes (Daubenmire 1959, Higgins et al. 1994). Grasses and forbs were consolidated whereas shrubs were identified to species.

Tall shrub (defined as ≥1 m tall and <12.8 cm dbh) density was measured within 4, 1 m by 10 m belt transects. Belt transects originated at plot center and ran in the 4 cardinal directions (Kennedy 1992, as modified from Stauffer and Peterson 1985).

Analytical Methods

Weighted average dbh, regardless of species, was calculated as described by West et al. (1976), using trees included in the basal area count. Total tall shrub/sapling densities were obtained by summing all tall shrubs and saplings encountered on belt transects, regardless of species.

Daubenmire cover classes were averaged by species across all 15 plots and rounded to the nearest whole number. Each species was then assigned a cover mid-point value (Daubenmire 1959, Higgins et al. 1994) based on the average Daubenmire class (i.e., an average Daubenmire score of 2 [6-25% canopy cover] receives a mid-point value of 15.5). Additionally, quadrat data were used to calculate the frequency with which deciduous shrubs occurred on each winter subrange (Higgins et al. 1994).

Statistical Methods

Analysis of variance was used to determine if habitat variables differed across study areas. Because many habitat variables are correlated (e.g., canopy cover is related to basal area [Uresk and Severson 1989] and litter

[Pase 1958]), principal component analysis also was used to reduce habitat data into a smaller more usable array of independent factors (McCown et al. 1991) that measured different dimensions in the data (Manly 1986).

All habitat data were rank transformed (Conover and Iman 1981). The level of statistical significance was set at $P \leq 0.05$. All analyses were performed using SYSTAT (Wilkinson 1990).

RESULTS

Environmental

During 1992, average daily minimum temperature ranged from -4.8°C in February to 12.3°C in July; average daily maximum temperature ranged from 0.9°C in December to 26.6°C in August (NOAA 1992). During 1993, the average daily minimum temperature ranged from -12.5°C in January to 12.9°C in August; average daily maximum temperatures ranged from -2.8°C in February to 25.7°C in August (NOAA 1993).

The winter of 1992 was unusually mild with minimal snowpack, which melted by mid-January. Temperatures from January - March in 1992 averaged 5.0°C above normal while total precipitation was 0.41 cm below normal; however, precipitation data from January were incomplete (NOAA 1992). Snow rarely covered the ground for more than 2 or 3 days in 1992. The winter of 1993 was more severe. Temperatures from January - March averaged 1.8°C below normal. Although total precipitation was 1.50 cm below

normal (precipitation data from January were incomplete [NOAA 1993]), colder than normal temperatures during January (-2.0°C) and February (-4.8°C) 1993, resulted in deeper and more persistent snow across all study areas than was present in 1992. During 1993, snow was present in shaded areas, such as draws, into March.

Temperatures from April - August (i.e., spring/summer) 1992 and 1993 averaged 0.5°C and 1.4°C below normal, respectively (NOAA 1992, NOAA 1993). Total precipitation over the spring/summer period was 6.05 cm below normal in 1992 and 5.05 cm above normal in 1993.

Deer Density

Density estimates were determined only once in 1992 due to a lack of adequate snowfall; density was not determined in 1993. Deer density ranged from a high of 130 deer/km^2 at Badger to a low of 28 deer/km^2 at Bear Ridge (Fig. 2). Densities at Burke/Larson (63 deer/km^2), Crow Creek (61 deer/km^2), and Sleep/Nicholas (57 deer/km^2) were similar and fell between the two extremes (Fig. 2).

Habitat

Disregarding stock tanks on private land, Burke/Larson and Crow Creek were the only study sites with permanent sources of free water. Intermittent streams (present on all winter subranges) were dry in spring 1992, but ran for a brief period in spring 1993 due to above normal precipitation (discussed above).

Prior to the start of this study Burke/Larson was commercially logged and many large, fresh slash piles were present at Burke/Larson in winter 1992. Additionally, deciduous stands (primarily bur oak and ironwood Ostrya virginiana) also were thinned at Burke/Larson in 1993. All other study sites also were logged or thinned to lesser degrees during the course of this study. Portions of Badger were logged in the spring of 1993 and small areas of pine were cleared at Crow Creek in 1992. Firewood/fuelwood cutting was allowed at Bear Ridge in 1992 and bur oak draws were thinned at Sleep/Nicholas in 1992.

Mean elevation, which differed among all winter subranges (Tukey's HSD = 13908.268, 476 df, $P \leq 0.05$), was highest at Bear Ridge ($\bar{x}$ = 4462.9 m ± 22.1) and was followed in descending order by Badger ($\bar{x}$ = 4374.4 m ± 22.1), Sleep/Nicholas ($\bar{x}$ = 4264.2 m ± 24.6), Burke/Larson ($\bar{x}$ = 4142.4 m ± 22.1), and Crow Creek ($\bar{x}$ = 4016.2 m ± 22.1). Slope at Bear Ridge was steeper (Tukey's HSD = 21777.127, 495 df, $P \leq 0.05$) than at any other study area. Distance to the closest road was greater (Tukey's HSD = 26042.161, 487 df, $P \leq 0.05$) at Crow Creek ($\bar{x}$ = 451.0 m ± 21.2) than on any other study area (overall $\bar{x}$ = 221.7 m ± 21.4).

Forested areas in the NBH were dominated by ponderosa pine and bur oak was the most common understory species. Agricultural areas in the NBH are dominated by agricultural

crops, grasses, and forbs, however; bur oak-dominated deciduous draws were often associated with agricultural areas. Deciduous (F = 2.647, 4 df, P = 0.033), coniferous (F = 46.849, 4 df, P < 0.001), and total (i.e., deciduous plus coniferous) (F = 32.883, 4 df, P < 0 001) canopy cover, differed by study area (Table 1). Average dbh (F = 31.002, 4 df, P < 0.001), basal area (F = 27.508, 4 df, P < 0.001), and tall shrub/sapling density (F = 24.312, 4 df, P < 0.001) also differed among winter subranges (Table 1).

Ground cover also differed among winter subranges. Grass (F = 18.979, 4 df, P < 0.001), forb (F = 2.842, 4 df, P = 0.024), horizontal juniper (Juniperus horizontalis) (F = 8.373, 4 df, F < 0.001), bare soil (F = 10.053, 4 df, P < 0.001), litter (F = 16.205, 4 df, P < 0.001), and slash (F = 6.139, 4 df, P < 0.001) differed among study areas (Table 2). Common juniper (Juniperus communis) (F = 0.750, 4 df, P = 0.558), Oregon grape (Berberis repens) (F = 1.781, 4 df, P = 0.131, agricultural (F = 1.005, 4 df, P = 0.405), bur oak (F = 1.000, 4 df, P = 0.407), and rock (F = 2.242, 4 df, P = 0.064) did not differ among winter subranges (Table 2).

Although common, the sparse distribution and low canopy coverage of many shrubs (e.g., chokecherry [Prunus virginiana], serviceberry [Amelanchier spp.], rose [Rosa spp.], etc.) generally led to classification under the lowest Daubenmire coverage class (i.e., 0-5%). As a

result, statistical analysis could not be performed due to a lack of variance. However, it was possible to compare the frequency with which these shrubs occurred on study areas. Generally, shrubs were encountered more often at Badger and Bear Ridge (Table 3).

Although usually reported as a common understory component in the Black Hills, bearberry (Arctostaphylos uva-ursa) seldom occurred on winter subranges in this study. Like other shrubs, bearberry was encountered more frequently at Badger (7%) and Bear Ridge (8%) than it was at Burke/Larson (0%), Crow Creek (0%), or Sleep/Nicholas (2%). Where it occurred, bearberry always was classified under the lowest Daubenmire cover class (i.e., 0-5% canopy cover) and could not be statistically analyzed due to a lack of variance.

Three principal components explained 85.8% of the variance among six selected habitat variables (i.e., total canopy cover, basal area, total tall shrub/sapling, distance to nearest adjacent edge, litter, and bare soil) (Table 4). Total canopy cover, basal area, litter, and total tall shrub/sapling loaded heavily in the first factor which represented overstory influences (Table 4). Distance to adjacent edge and the amount of bare soil were the most important variables explained by the second and third factors, respectively (Table 4). The overstory component (factor one) at Badger and Bear Ridge differed (Tukey's HSD

= 0.820, 493 df, $P \leq 0.05$) from that at Burke/Larson, Crow Creek, and Sleep/Nicholas (Fig. 3). The edge component (factor 2) was greater (Tukey's HSD = 0.969, 493 df, $P \leq 0.05$) at Burke/Larson than it was at Crow Creek, Bear Ridge, and Sleep/Nicholas, but similar (Tukey's HSD = 0.969, 493 df, $P \leq 0.05$) to Badger (Fig. 3). The disturbance component (factor 3) was greater (Tukey's HSD = 0.970, 493 df, $P \leq 0.05$) at Burke/Larson than it was at Badger, Bear Ridge, or Sleep/Nicholas but similar (Tukey's HSD = 0.970, 493 df, $P \leq 0.05$) to Crow Creek (Fig. 3).

DISCUSSION

Since the early 1970's harvest management of white-tailed deer in the NBH has been conservative, however, long term population trends have been steadily downward (Griffin et al. 1992). Additionally, Griffin et al. (1992:1) reported "most management agencies support the belief that habitat deterioration has been the primary cause of the deer decline." Comparisons of historical records to recent data (Gartner and Thompson 1972) indicated that the Black Hills have changed extensively since the mid 1870's. Fire suppression following settlement allowed ponderosa pine to invade grasslands (Gartner and Thompson 1972) and increase its distribution by one third (Richardson and Peterson 1974).

The higher overstory component (Fig. 3) indicated that Badger and Bear Ridge are predominantly ponderosa pine

dominated environments. The reverse was true of Burke/Larson, Crow Creek, and Sleep/Nicholas, which were located primarily on private land with more non-forested, agricultural land. Richardson and Peterson (1974) stated that the trend toward pine dominance was detrimental to wildlife. Density estimates (Fig. 2) indicated that the non-supplemented, forested area (Bear Ridge) only supported half as many deer as agricultural subranges (i.e., Burke/Larson, Crow Creek, and Sleep/Nicholas).

As a result of a strong division between forested and agricultural land, edge effects (factor 2) were greatest at Burke/Larson (Fig. 3). Bare soil level also was highest at Burke/Larson (Table 2) and may be an index to disturbance (factor 3) (i.e., logging, which occurred just prior to the initiation of this study) (Fig. 3). Bare soil also may reflect agricultural practices, however, with the exception Burke/Larson, disturbance did not differ ($P > 0.05$) between agricultural and forested winter subranges.

Kennedy (1992) reported that NBH deer preferred areas with higher basal area and canopy cover, which provided thermal cover in winter. Because distance to the closest edge is greater at Burke/Larson, deer would expend more energy to reach feeding sites, and the lower canopy cover (due to logging) may increase the amount of energy deer expend to maintain body temperature.

Although tall shrub/sapling measurements were useful for differentiating among winter subranges, Daubenmire cover classes were not an effective means to sample many species of shrubs. Creeping (i.e., Oregon grape and horizontal juniper) or hedge-like (i.e., common juniper) shrubs can be surveyed using Daubenmire cover classes, however, most deciduous shrubs were consistently classified in the lowest cover class and could not be statistically analyzed due to a lack of variance. Partially as a result of growth form (Greig-Smith 1957), season (Greig-Smith 1957), and browsing pressure (overbrowsed acreage has increased in the Black Hills [Wallin and Rice 1980, 1981]), deciduous shrubs do not contribute much to ground cover in the NBH. Although this is detected with Daubenmire cover classes, the results are misleading. Uncritical use of Daubenmire cover classes in the NBH leads to the conclusion that winter subranges do not differ. However, using frequency of occurrence, deciduous shrubs tended to be more common on forested study areas (i.e., Badger and Bear Ridge) (Table 3). These conclusions are supported by tall shrub/sapling data (Table 1). Thus, if the purpose is to characterize study areas, Daubenmire cover classes are not the most appropriate survey method.

Historically, bearberry has been an important understory component in the Black Hills (Black Hills National Forest 1994) but seldom occurred on subranges

surveyed during this study (of 500 random plots, bearberry occurred 17 times and canopy cover never exceeded 5%). Hill (1946) determined bearberry comprised 8.1% of available forage on NBH winter range and Schneeweis (1969) determined bearberry comprised 7.4% of the forage available with a 2.54 cm snow depth. During this study, bearberry never accounted for more than 5% of ground cover.

MANAGEMENT IMPLICATIONS

Winter subranges in the NBH can be classified according to their degree of forestation and the influence of agriculture. Low overstory components (i.e., total canopy cover, basal area, litter, and tall shrub/sapling numbers) were the most important factors distinguishing agricultural lands from forested areas. Distance to nearest adjacent edge reflected the degree of interspersion between feeding and resting/loafing sites, which can influence deer use of feeding sites (Dusek 1987). Bare soil can indicate disturbance and also may be a useful predictor of the amount of agricultural land present on an area.

Chapter 3

Fecal indices to white-tailed deer winter nutritional condition in the northern Black Hills, South Dakota.

INTRODUCTION

Over the past 50 years, winter diets of white-tailed deer (Odocoileus virginianus dacotensis) inhabiting the northern Black Hills (NBH) of South Dakota have been documented to identify dietary indicator species and assess carrying capacity of winter range (Hill and Harris 1943, Hill 1946, and Schneeweis 1969). Species comprising the majority of diets consumed by deer included Oregon grape (Berberis repens), common juniper (Juniperus communis), and ponderosa pine (Pinus ponderosa), with proportions varying with winter severity. However, few studies have gone beyond simple diet descriptions. Furthermore, the relationship between diet composition and diet quality of this population is unknown.

Winter deaths usually result from chronic undernutrition rather than starvation (DelGiudice and Seal 1988). Use of fecal indices can provide information on recent nutritional history, which may reflect variation in habitat quality (Dinkines et al. 1991). Indices such as fecal nitrogen (FN) and phosphorus (FP) have been correlated with dietary nitrogen and phosphorus intake, respectively, for black-tailed deer (O. hemionus columbianus) (Leslie and Starkey 1985) and white-tailed deer (Howery and Pfister 1990). In addition, FN has been related to diet digestibility (Leslie and Starkey 1985) and weight changes in bighorn sheep (Ovis canadensis) (Hebert

et al. 1984) and elk (Cervus elaphus) (Gates and Hudson 1981). Generally, FN and FP are lowest in winter and highest in spring (Leslie and Starkey 1985).

Because severe winters can result in high mortality of deer populations and increased depredation to local ranchers, South Dakota Department of Game, Fish and Parks supplements some herds by planting food plots and distributing alfalfa (Medicago sativa) hay. However, no information is available on effects of supplementation on diet quality of deer in the northern Black Hills.

The objectives of this study were to evaluate variation in diet quality of white-tailed deer in the winter both temporally (i.e., as the season progressed from January to March) and spatially (i.e., across study areas). I hypothesized that diet quality of deer would be similar throughout winter and across subranges in the northern Black Hills. I also hypothesized that mature forages used as supplemental feed for deer in winter would not influence diet quality of subherds in the northern Black Hills.

STUDY AREA

Five study sites (Fig. 1) totaling 1744 ha were located westward from Spearfish, South Dakota, to the Wyoming border. Study sites (subranges) were delineated from locations of radio-collared deer (Kennedy 1992). Female deer had high fidelity for these 5 subranges over a two year period (1990-1992). All five subranges are

approximately located at 44° 30′ W latitude and range in longitude from 103° 50′ N to 104° 04′ N. Study areas (i.e., Badger [B], Burke/Larson [BL], Crow Creek [CC], Bear Ridge [BR], and Sleep/Nicholas [SN]) consist of a mixture of federal, state, and private land. A full description of the study area is provided in Chapter 2.

METHODS

Field Methods

Twenty, white-tailed deer fecal groups were collected from each of the five subranges at two week intervals during January-March 1992 and 1993. Only fresh pellet groups (Jenks et al. 1990) were gathered to ensure that feces were deposited within the 2-week period of intent. Fecal samples were stored frozen until processed.

Because isolated groups of mule deer (O. hemionus) were occasionally found on all study areas, efforts were made to avoid collecting pellet groups where mule deer were commonly observed. However, the northern half of the Bear Ridge study area supported a relatively large population of mule deer, which was difficult to avoid. When possible, visual confirmation was used to determine which deer species was currently in the area. When both white-tailed and mule deer were present, any pellet group that was questionable as to its origin, was not collected.

In addition to collecting fecal samples from study areas, fecal samples were obtained from 5 female white-

tailed deer collected from each study area in February 1992 and 1993. Fecal samples were stored frozen until processed.

Analytical Methods

Feces were dried at 60°C (Hinnant and Kothmann 1988) and blended (Davitt and Nelson 1980). The twenty individual pellet groups were then composited (Jenks et al. 1989) by equal weight forming one sample/study area/sampling interval, for a total of six composite samples/study area/winter.

Concentrations of fecal nitrogen (semi-micro Kjeldahl method [Jackson 1958]) and phosphorus (colorimetric analysis [Bolin and Standburg 1944]) were determined from composite samples and from those collected from individual animals by the South Dakota State University Soil Testing Laboratory.

Statistical Methods

Probability plots were used to test data for normality. A Bartlett's test was used to test for heterogeneous variances among study areas. If data violated either the assumption of normality or homogeneity of variance, analyses were performed on ranked data (Conover and Iman 1981). Analysis of variance was used to compare FN and FP levels from study area composites (SAC) to individual animals and test for main and interactive effects of year, study area, and group (i.e., SAC vs.

individuals). Analysis of variance also was used to test the *a priori* hypothesis that supplementally fed deer did not differ from non-supplemented animals and to test SAC's for main and interactive effects of year, study area, and collection period. Tukey's HSD was used when significant differences ($P \leq 0.05$) existed between study areas. SYSTAT (Wilkinson 1990) was used to perform all statistical analyses.

RESULTS

Levels of FN ($F = 0.142$, 1 df, $P = 0.708$) and FP ($F = 0.418$, 1 df, $P = 0.519$) (Table 5) did not differ when SAC levels were compared to those for individuals. In 1992, the average differences between SAC and individual levels were 0.13% for FN (Fig. 4) and 0.07% for FP (Fig. 5). Likewise, 1993 average differences between SAC and individual levels were only 0.05% and 0.06% for FN (Fig. 6) and FP (Fig. 7), respectively.

Study area by year ($F = 4.520$, 4 df, $P = 0.004$) and year by collection period ($F = 6.869$, 5 df, $P < 0.001$) interactions existed for FN data, therefore data were analyzed by year. In 1992, collection period affected ($F = 25.637$, 5 df, $P < 0.001$) FN levels. Concentrations of FN for collection period six were higher (Tukey's HSD = 0.006, 20 df, $P < 0.05$) than all other collection periods (Appendix 1) and were removed from further analyses to ensure conclusions reflected nutritional differences during

winter. After removal of collection period six, FN levels during collection period five were higher (Tukey's HSD = 0.004, 16 df, $P < 0.05$) than those of collection periods one and two but were similar (Tukey's HSD = 0.004, 16 df, $P > 0.05$) to FN levels during collection periods three and four (Fig. 8a). Thus FN levels for the fifth collection period in 1992 were considered a late winter values and were not excluded from analyses. In 1993, FN concentrations varied but did not differ ($F = 2.186$, 5 df, $P = 0.096$) intraseasonally (Fig. 8b), thus all collection periods were used in analyses.

Interactions between study area and year ($F = 4.693$, 4 df, $P = 0.003$) and between year and collection period ($F = 6.416$, 5 df, $P < 0.001$) also existed for FP data. When analyzed within years, collection period affected FP levels during 1992 ($F = 16.565$, 5 df, $P < 0.001$). Like FN, FP concentrations during the sixth collection of 1992 were higher (Tukey's HSD = 44.716, 20 df, $P < 0.05$) than the previous five collection periods (Appendix 2) and were removed from analyses. After removal of collection period 6, FP concentrations in collection period five were higher (Tukey's HSD = 34.709, 16 df, $P < 0.05$) than FP values during collection periods one and two (Fig. 8c). Additionally, 1992 FP levels during collection period four were higher (Tukey's HSD = 34.709, 16 df, $P < 0.05$) than those during collection period two (Fig. 8c). In 1993, FP

concentrations varied but did not differ (Tukey's HSD = 34.709, 16 df, $P > 0.05$) intraseasonally (Fig. 8d).

Fecal nitrogen levels of supplemented deer were higher than those of non-supplemented deer in 1992 ($F = 71.847$, 1 df, $P < 0.001$) (Table 6) and 1993 ($F = 92.777$, 1 df, $P < 0.001$) (Table 6). Fecal phosphorus concentrations also indicated that supplemented deer consumed higher quality diets than non-supplemented deer in 1992 ($F = 52.408$, 1 df, $P < 0.001$) and 1993 ($F = 94.890$, 1 df, $P < 0.001$) (Table 6). Additionally, in 1993, intraseasonal tendencies in FN and FP data at Badger differed from those observed on non-supplemented areas (Fig. 8b, 8d). Furthermore, while diet quality on non-supplemented areas declined in 1993 (results below), FP concentrations at Badger increased (Fig. 9) in 1993 and increases in FN approached significance (Fig. 9). Thus, in order to focus on diet quality trends resulting from consumption of natural forages, Badger was excluded from further analyses.

When Badger was dropped from analysis, no interactions existed and years were pooled to increase sample size. Among non-supplemented areas, FN and FP concentrations declined ($F = 9.574$, 1 df, $P = 0.007$ and $F = 7.143$, 1 df, $P < 0.001$, respectively) from 1992 to 1993 (Table 6). Fecal nitrogen concentrations indicated that deer at Burke/Larson consumed a higher (Tukey's HSD = 0.009, 16 df, $P \leq 0.05$) quality diet than deer on Bear Ridge or Sleep/Nicholas, and

deer at Crow Creek consumed a higher (Tukey's HSD = 0.009, 16 df, $\underline{P} \leq 0.05$) quality diet than deer on Bear Ridge (Fig. 9). Fecal phosphorus levels indicated that deer on Burke/Larson and Crow Creek consumed a higher (Tukey's HSD = 69.584, 16 df, $\underline{P} \leq 0.05$) quality diet than deer on Bear Ridge or Sleep/Nicholas (Fig. 10).

DISCUSSION

The use of FN has been criticized because plant secondary compounds such as tannins may artificially inflate FN levels (Hobbs 1987, Robbins et al. 1987a). Mould and Robbins (1981) observed elevation of FN when elk were fed an experimental diet high in tannins. However, Caughley and Sinclair (1994) stated that feeding trials represent abnormal situations and when animals are allowed to choose their own diet, a positive relationship occurs between FN and dietary nitrogen.

During this study deer chose diets containing 37.4% grasses and winter browse (Chapter 4). Both grasses and most deciduous winter browse stems are low in tannins (Robbins et al. 1987a,1987b). While the remaining dietary components could have contained tannins, comparisons of FN and FP concentrations did not indicate FN levels had been altered. Mubanga et al. (1985) noted that FP could be a reliable indicator of dietary quality while not being susceptible to complications caused by phenolics and tannins. Throughout the duration of this study, trends in

FN and FP were similar (Fig. 9; Fig. 10) and FN was strongly correlated with FP (r^2 = 0.88) (Fig. 11). Further, despite a rise in the consumption of tannin-containing coniferous browse from 1992 ($\bar{x}$ = 20.652 ± 2.456) to 1993 ($\bar{x}$ = 37.141 ± 2.456) (Chapter 4), FN levels among non-supplemented deer were lower in 1993. As a result, tannins were not considered problematic and FN differences detected between years and among study areas likely reflected nutritional differences among sub-herds.

Other potential problems could arise if FN and FP levels fluctuate with age and/or sex. Cook et al. (1994) determined that the growth and development of the alimentary tract in juvenile elk had a greater influence on fecal nitrogen than dietary variables until calves were 20-25 weeks old. However, Hebert et. al. (1984) found no difference between FN levels of adult and young (6-11 month) bighorn sheep. Because fecal samples in the NBH were collected after the digestive system of white-tailed deer has matured (Short 1964) and FN begins to track dietary nitrogen, the inclusion of pellet groups from juvenile animals would not alter results.

Beier (1987) reported that female white-tailed deer at the George Reserve in Michigan consistently consumed a higher quality diet than males, resulting in females having higher FN levels. The differences between females and males were most prominent during December and January

(Beier 1987). Although study area composites (SAC) probably include pellet groups from males, FN levels did not differ significantly between SAC and individual deer (only female deer were collected). Therefore intersexual differences did not appear to compromise SAC accuracy during this study.

Fecal indices gave similar results when SAC and intestinal feces were compared, which supported findings of Hebert et al. (1984). During an eight month trial, Hebert et al. (1984) found FN levels of individual captive bighorn sheep differed only during one month from composite samples collected randomly from the paddock. Thus, composite samples likely reflected diet quality changes among NBH subherds.

Winter 1992 was unseasonably warm (NOAA 1992) with minimal snowpack; snow occurred in early January. In contrast, winter 1993 was unseasonably cold (NOAA 1993); snow covered all study areas until the end of February, and where drifted, snow was present until March. The unusually warm winter of 1992 led to an early spring. As a result, FN and FP levels were stable from collection periods one to five, then increased sharply in collection period six (Fig. 8a and Fig. 8c, respectively). This increase undoubtedly reflected spring "green up" and incorporation of new growth into diets. Increased FN corresponding to consumption of new growth has been observed for white-tailed deer at

George Reserve in Michigan (Beier 1987) and bighorn sheep in British Columbia (Hebert et al. 1984). In 1993, FN and FP levels varied by study area but did not differ temporally (Fig. 8b and Fig. 8d, respectively). As a result, the hypothesis that fecal indices would remain stable throughout winter was rejected during 1992 (even after collection period six was removed) but not during 1993.

Although not significantly different, FN and FP levels in the third period of 1993 tended to be higher than FN and FP levels in periods 2 and 4 of 1993 (Fig. 8b and Fig. 8d, respectively) and may be a result of a snow free period that occurred mid-winter. At the end of the third collection period in 1993, cold temperatures and 20.3-30.5 cm (8-12 inches) of snow over a six day period ended a warming trend that had exposed grasses and other low-growing vegetation. Snow depths greater than 7.6 cm strongly influenced the diet of white-tailed deer on the George Reserve in Michigan (McCullough 1985) and Beier (1987) noted FN levels increased significantly during snow free (i.e., snow depth $\leq$ 7.6 cm) periods.

Supplemental feed made available to deer on the Badger study area, consisted primarily of high quality alfalfa hay and corn (Zea mays). Fecal indices indicated that deer on the supplemented subrange consumed a better quality diet than their non-supplemented counterparts (Table 6). As a

result, the hypothesis that supplemental feeding would not affect diet quality was rejected. Griffin (1991) reported that native grassland forages in northwestern South Dakota had lower crude protein levels than alfalfa and wheat (Triticum aestivum). Johnson et al. (1987) reported that white-tailed deer in Louisiana with access to food plots containing agronomic forages had higher fecal nitrogen levels and weighed more than non-supplemented animals. In contrast, Johnson and Dancak (1993) found food plot availability had no effect on deer condition, and concluded that food plots are unlikely to dramatically affect a healthy deer herd that is within range carrying capacity. The positive response of NBH deer to supplementation may indicate winter subranges are near capacity.

With the exception of Badger, fecal indices also indicated that deer tended to consume a lower quality diet in 1993 (Fig. 9, 10). Provision of supplemental feed at the Badger study area is based on ambient temperature and snow depth. During 1992, deer were fed once per week, however, in 1993, feeding frequency was increased to three times per week. Thus the elevation of fecal indices at Badger in 1993 might have resulted from increased feeding frequency. Furthermore, as spring approached and supplementation was phased out, the diet quality differences between supplemented and non-supplemented animals lessened (Fig. 8a, 8b, 8c, 8d).

When Badger was excluded from analyses, differences also existed among FN and FP levels on non-supplemented study areas (Table 6). Therefore, the hypothesis that diet quality would not differ across winter subranges also was rejected. Deer at Burke/Larson and Crow Creek consumed higher quality diets than deer at Bear Ridge and Sleep/Nicholas. Although FN and FP concentrations indicated that deer at Bear Ridge and Sleep/Nicholas consumed similar quality diets, deer densities at Bear Ridge were half the densities observed on other non-supplemented areas, indicating the non-supplemented forested area was capable of supporting fewer deer.

Weight loss has been associated with FN concentrations below 1.3% for bighorn sheep (Irwin et al. 1993) and 1.6% for elk (Gates and Hudson 1981). These levels represent the threshold below which bighorn and elk are consuming submaintenance diets. Although no FN threshold level has been reported for deer, 1.9% - 2.0% may represent that threshold. Winter diets are often at, or below maintenance level (Harris 1945, Ammann et al. 1973) and winter FN levels for deer rarely rise above 2.0 (Leslie and Starkey 1985, Leslie et al. 1989). Despite higher density, Badger FN levels ranged around the 1.9% - 2.0% level during both years, while FN of non-supplemented animals fell below this level (Fig. 9). Differences between supplemented and non-

supplemented deer were more pronounced in the winter of 1993 (Fig. 9).

Weight loss thresholds for FP also have not been established for deer, however, assuming 1.9% - 2.0% is a reasonable estimate for FN, it may be possible to calculate a critical FP value. During this study FN levels were correlated with FP levels (r^2 = 0.877, Fig. 11). Using the regression equation:

$$FP = FN(0.564) - 0.572$$

the predicted threshold value for FP was calculated at 0.50% - 0.56%, which supported findings of Leslie and Starkey (1985).

MANAGEMENT IMPLICATIONS

Despite higher density (Fig. 2), deer at Badger consumed a higher quality diet than non-supplemented animals. Although all non-supplemented deer had access to agricultural stubble fields, fecal indices of non-supplemented deer still did not approach the FN and FP levels attained at Badger (Fig. 9 and Fig. 10, respectively). While deer at Sleep/Nicholas and Bear Ridge consumed similar quality diets (Fig. 9 and Fig. 10), Sleep/Nicholas supported approximately twice as many deer (Fig. 2). Kennedy (1992) found agricultural fields to be important foraging sites to deer in the NBH. The results of the current study indicate agricultural fields appear to

positively affect diet quality and may be largely responsible for maintaining the NBH deer population.

If FN and FP threshold estimates are correct, NBH winter subranges supplied sub-marginal diets to deer even during the unusually mild winter of 1992, despite access to agricultural fields. However, with the exception of Badger in 1993, both FN and FP data indicated that diet quality did not decline as winter progressed (Fig. 8a, 8b, 8c, 8d), although overall diet quality tended to be lower in winter 1993.

Unlike most physiological indices, which require that animals be captured or sacrificed, fecal indices are non-lethal. Many animal rights organizations oppose any lethal means of collecting data, and when working near inhabited areas public safety must be given the highest priority. Although some physiological indices respond rapidly to dietary changes (i.e., blood indices) most tend to reflect chronic nutritional problems and are of limited use for intraseasonal monitoring. The results of this study have shown that FN and FP are a sensitive method to monitor intraseasonal dietary quality of white-tailed deer, capable of detecting diet quality changes over a two week period.

Despite higher densities, supplemental feeding at Badger maintained deer around maintenance levels, while non-supplemented deer tended to be below maintenance levels. Although supplemental feeding effectively improves

diet quality, it not practical or cost effective on a large scale and does little to reduce depredation problems. Management agencies must still rely on habitat manipulation and/or hunting to improve range condition. Using fecal indices, both intra and interseasonal responses to management practices can be monitored, allowing agencies to take a more proactive approach to management.

Chapter 4

Winter Diet of White-Tailed Deer in the Northern Black Hills, South Dakota

INTRODUCTION

Winter diet composition can influence diet quality (Beier 1987) and nutritional condition (Johnson et al. 1987) of white-tailed deer (Odocoileus virginianus). Modeling revealed dietary energy (partially a function of composition and digestibility) affected winter mortality among mule deer (O. hemionus) (Hobbs 1989). In mild winters, consumption of plants with low cell wall content (i.e., immature grasses, leaves, and forbs) may improve condition among mule deer (Hobbs 1989). Furthermore, these easily digestible forages need only be present in small amount to have substantial impacts on winter mortality (Hobbs 1989).

Diet composition is affected by weather and forage preference. Snow levels greater than 7.6 cm altered the diet (McCullough 1985) and diet quality (Beier 1987) of white-tailed deer on the George Reserve in Michigan. Although snow levels influence forage availability, deer forage preferences play a large role in determining diet composition. During early winter, white-tailed deer in Quebec relied on 1-4 preferred forage species while ignoring others (Brown and Doucet 1991). As key species availability declined, less desirable species were gradually included in the diet, and by the end of winter, deer diets contained 16 forage species. The order in which species were incorporated into the diet was similar across

3 years leading Brown and Doucet (1991) to conclude that understanding forage preferences and the temporal pattern with which forages are included into winter diets may be used to determine habitat quality.

Although winter diets of white-tailed deer in the northern Black Hills (NBH) of South Dakota have been studied (Hill and Harris 1943, Harris 1945, Hill 1946, Gastler et al. 1951, Schneeweis 1969, Schneeweis et al. 1972), there have been no intraseasonal diet composition comparisons. Additionally, the effects of diet supplementation by South Dakota Department of Game, Fish and Parks on deer in the NBH are unknown. The fundamental purpose of this study was to evaluate the winter diets of white-tailed deer both intraseasonally (i.e., as the season progressed from January to March) and spatially (i.e., across study areas). A secondary purpose was to examine effects of supplemental feeding on the winter diet dynamics of white-tailed deer in the NBH. I hypothesized that diet composition would not vary between years and would not change as the season progressed. I also hypothesized that supplemental feeding would not alter diet composition and that diets would not differ among winter subranges.

STUDY AREA

Five study sites (Fig. 1) totaling 1744 ha were located westward from Spearfish, South Dakota, to the Wyoming border. Study sites (subranges) were delineated

from locations of radio-collared deer (Kennedy 1992). Female deer had high fidelity for these 5 subranges over a two year period (1990-1992). All five are approximately located at 44° 30′ W latitude and range in longitude from 103° 50′ N to 104° 04′ N. Study areas (i.e., Badger [B], Burke/Larson [BL], Crow Creek [CC], Bear Ridge [BR], and Sleep/Nicholas [SN]) consist of a mixture of federal, state, and private land. A full description of the study area is provided in chapter 2.

METHODS

Field Methods

Twenty, white-tailed deer fecal groups were collected from each of the five subranges at two week intervals during January-March 1992 and 1993. Only fresh pellet groups (Jenks et al. 1990) were gathered to ensure that feces were deposited within the 2-week period of intent. Fecal samples were stored frozen until processed.

Because isolated groups of mule deer (O. hemionus) were occasionally found on all study areas, efforts were made to avoid collecting pellet groups where mule deer were commonly observed. However, the northern half of the Bear Ridge study area supported a relatively large population of mule deer which was difficult to avoid. When possible, visual confirmation was used to determine which species was currently in the area. When both white-tailed and mule

deer were present, any pellet group that was questionable as to its origin, was not collected.

Analytical Methods

Feces were dried at 60°C (Hinnant and Kothmann 1988) and blended (Davitt and Nelson 1980). The twenty individual pellet groups were then be composited by equal weight forming one sample/study area/sampling interval, for a total of six composite samples/study area/winter.

Composite samples were then prepared for microhistological analysis as outlined by Davitt and Nelson (1980). Blended fecal material was soaked in ethanol and bleach to remove plant pigments. Plant fragments were then stained and permanently mounted on microscope slides. Diet composition was determined using five slides per composited sample and 20 random observations per slide (Holechek and Vavra 1981) (100 observations per sample). Holechek and Vavra (1981) determined that this combination adequately sampled species comprising $\geq$ 10 % of the diet within 20% of the mean at the 90% confidence level; this method also will sample species comprising $\leq$ 5% of the diet but with less accuracy. Slides were examined under 100 power magnification (Stewart 1967) and diet composition was determined using the area measurement method described by Stewart (1967).

Statistical Methods

All diet composition data were arc-sine transformed after taking the square root (Massey et al. 1994). Probability plots were used to test data for normality. A Bartlett's test was used to test for heterogeneous variances among study areas. If data violated either the assumption of normality or homogeneity of variances, analyses were performed on ranked data (Conover and Iman 1981). Analysis of variance was used to test each dietary component for the main and interactive effects of study area, year, and period. The level of significance was set at $P \leq 0.05$. A Tukey's HSD was used when significant differences existed among study areas and/or periods. All statistical analyses were performed using SYSTAT (Wilkinson 1990).

RESULTS

Fifty-four species of plants were identified from fecal samples during this study; thirteen browse species (i.e., trees and shrubs), two agricultural species (alfalfa [Medicago sativa] and corn [Zea mays]), fifteen grasses, ten forbs (excluding alfalfa) , and twelve unknowns. However, of the 54, only 3 species (Oregon grape (Berberis repens), ponderosa pine (Pinus ponderosa), and juniper spp. [Juniperus communis and J. horizontalis both occur on study sites but are indistinguishable in fecal samples]) consistently accounted for $\geq$ 5% of the diet. Plant species

were combined into 8 forage categories to reduce the number of variables and aid interpretation. The eight categories examined were ponderosa pine (PIPO), Oregon grape (BERE), juniper spp. (JUSP), collective shrubs (SHRUB), collective grasses and agricultural crops (GRAG), collective forbs (FORB), corn, and collective unknowns (UNK) (Table 7).

Study area by year interactions existed for PIPO (F = 4.597, 4 df, P = 0.009), JUSP (F = 2.856, 4 df, P = 0.051), SHRUB (F = 3.762, 4 df, P = 0.019), corn (F = 4.779, 4 df, P = 0.007), and UNK (F = 8.592, 4 df, $P < 0.001$). As a result years were analyzed separately for these dietary components.

The winter of 1992 was unseasonably warm with little snow (Chapter 2). Higher fecal indices during the sixth collection period of 1992 (Chapter 3) is very likely the result of an early spring. Thus to ensure that conclusions were truly based of winter diets of white-tailed deer, the sixth collection period of 1992 was dropped from dietary analyses.

Intraseasonal temporal trends in diet composition differed between years. The winter diet of NBH deer in 1992 displayed a gradual transition from an early winter to a late winter diet (Fig. 12). Oregon grape consumption declined as the season progressed, comprising a smaller (Tukey's HSD = 53.825, 16 df, $P \leq 0.05$) proportion of the diet in late winter than early winter (Fig. 12). In

contrast, more GRAG (Tukey's HSD = 36.799, 16 df, $P \leq 0.05$) was consumed in late winter than early winter (Fig. 12).

Intraseasonal trends in 1993 also showed the transition from an early winter to a late winter diet but due to mid-winter fluctuations in snow depth the progression is not as smooth (Fig. 13). Ponderosa pine consumption was higher (Tukey's HSD = 70.270, 20 df, $P \leq 0.05$) during early winter than late winter while GRAG contributed more (Tukey's HSD = 63.217, 20 df, $P \leq 0.05$) to deer diets in late winter than early winter (Fig. 13).

Supplemented and non-supplemented deer consumed different diets. In 1992, supplemented deer consumed more corn ($F = 42.238$, 1 df, $P < 0.001$) than non-supplemented deer (Table 8). Corn was not present in the diets of non-supplemented deer in 1992 (Table 8). Other forage categories did not differ ($P > 0.05$) in 1992 (Table 8). In 1993, Oregon grape ($F = 1.045$, 1 df, $P = 0.319$), GRAG ($F = 2.417$, 1 df, $P = 0.136$), and FORB ($F = 4.170$, 1 df, $P = 0.055$) were the only dietary components that did not differ (Table 8). Unlike 1992, some corn was consumed by non-supplemented deer. Non-supplemented deer only had access to corn that ranchers occasionally fed to cattle, as a result, it was not an important dietary component (Table 8).

Although diet composition differences between supplemented and non-supplemented deer were more pronounced

in 1993, fecal indices indicated that supplemented deer were consuming a higher quality diet during both 1992 and 1993 (Chapter 3). Thus, to concentrate on winter dietary differences among non-supplemented deer, Badger was excluded from further analyses.

When supplemented animals were removed from analyses, area by year interactions occurred for PIPO (F = 6.543, 3 df, P = 0.004), BERE (F = 3.193, 3 df, P = 0.052), and corn (F = 5.969, 3 df, P = 0.006), and as a result, they were compared across years. Juniper (F = 3.020, 3 df, P = 0.060), SHRUB (F = 2.969, 3 df, P = 0.063), GRAG (F = 1.068, 3 df, P = 0.390), and FORB (F = 0.275, 3 df, P = 0.843) were not affected by interactions. Deer consumption of GRAG (F = 0.233, 1 df, P = 0.636) was similar in 1992 and 1993 (Table 7) but was influenced by period (F = 7.199, 5 df, P = 0.001) (Fig. 12 and Fig. 13, respectively, Appendix 3). Differences in JUSP consumption approached significance (F = 4.322, 1 df, P = 0.054), with deer tending to consume more JUSP in 1993 (Table 7). Across all non-supplemented subranges deer consumed more SHRUB (F = 13.256, 1 df, P = 0.002) and less FORB (F = 6.588, 1 df, P = 0.021) in 1993 (Table 7). Although PIPO consumption was similar (F - 0.251, 1 df, P = 0.628) at Burke/Larson in 1992 and 1993, PIPO consumption was greater in 1993 at Crow Creek (F = 29.824, 1 df, P < 0.001) and Bear Ridge (F = 53.342, 1 df, P < 0.001), while 1993 increases at

Sleep/Nicholas approached significance (F = 3.765, 1 df, P = 0.084) (Table 7). Oregon grape consumption did not differ significantly between 1992 and 1993 at Burke/Larson (F = 0.675, 1 df, P = 0.433) but was less in 1993 at Crow Creek (F = 8.450, 1 df, P = 0.017), Bear Ridge (F = 19.494, 1 df, P = 0.002), and Sleep/Nicholas (F = 72.024, 1 df, P < 0.001) (Table 7). Corn was not an important dietary component on non-supplemented areas, and as a result, showed no significant differences (P > 0.05) between years on any study area (Table 7).

The diet composition of non-supplemented deer also varied among winter subranges. Although the consumption of JUSP (F = 2.868, 3 df, P = 0.069) and FORB (F = 0.902, 3 df, P = 0.462) did not differ significantly among subranges in 1992 or 1993 (Table 7), differences in GRAG consumption among subranges approached significance (F = 3.145, 3 df, P = 0.054), with deer on Bear Ridge tending to consume less GRAG in both years (Table 7). Additionally, deer on Bear Ridge and Sleep/Nicholas consumed more (Tukey's HSD = 34.655, 16 df, $P \leq 0.05$) SHRUB than deer on Burke/Larson or Crow Creek in 1992 and 1993 (Table 7).

In 1992, deer at Burke/Larson consumed more PIPO (Tukey's HSD = 47.875, 12 df, $P \leq 0.05$) than deer on any other study area, while deer at Crow Creek consumed less PIPO (Tukey's HSD = 47.875, 12 df, $P \leq 0.05$) than deer on Sleep/Nicholas (Table 7). Burke/Larson deer also consumed

less BERE (Tukey's HSD = 35.933, 12 df, $P \leq 0.05$) than any other non-supplemented animals in 1992 (Table 7). Furthermore, BERE consumption in 1992 varied among collection periods (Fig. 12). Corn did not appear in the diets of non-supplemented animals in 1992 (Table 7).

Differences among non-supplemented subranges also occurred in 1993. Pine consumption did not differ among study areas ($F = 2.410$, 3 df, $P = 0.108$) (Table 7) but did vary with collection period ($F = 7.274$, 5 df, $P = 0.001$) in 1993 (Fig. 13). Unlike 1992, corn was consumed by deer on some non-supplemented study areas in 1993. Corn comprised almost 3% of the diet consumed by deer at Crow Creek. However, corn was present in trace (i.e., <1%) amounts at Sleep/Nicholas and did not occur in diets of deer on Burke/Larson or Bear Ridge (Table 7). As a result, differences in corn consumption approached significance ($F = 2.853$, 3 df, $P = 0.072$). In 1993, deer at Burke/Larson consumed more (Tukey's HSD = 42.675, 15 df, $P \leq 0.05$) BERE than deer at Sleep/Nicholas (Tale 8) and BERE consumption varied with collection period (Fig. 13).

DISCUSSION

Deer fed in hayed agricultural fields. These stubble fields consisted of pasture mixtures containing grasses (e.g., intermediate wheatgrass [*Agropyron intermedium*] and western wheatgrass [*A. smithii*]) as well as alfalfa, sweetclover (*Melilotus* spp.), and other forage crops. Due

to the difficulty differentiating among grass species and the inability to determine whether grasses were consumed from natural areas or agricultural fields, grasses and agricultural crops were combined for the purposes of this study.

Diet composition of white-tailed deer changed from early January to late March, thus the hypothesis that deer diets would not change as the season progressed was rejected. Temporal changes in diet composition reflected changing importance of dietary components as the season advanced and seemed to be related to snow depth. Temporal changes in 1992 were gradual and may represent the change to a spring diet. Consumption of BERE was higher during early winter and declined as spring approached (Fig. 12). In contrast, GRAG initially comprised a small proportion of the diet but increased as grass and agricultural fields began to green (Fig. 12). Plants are most nutritious and digestible when actively growing (Stoddart et al. 1955). The incorporation of "new growth" into the diet also likely explains the increasing trend observed in diet quality in 1992 (Chapter 3).

Intraseasonal diet composition changes during 1993 also show a seasonal progression, although the primary species change (discussed below) and the pattern was disrupted by mid-winter fluctuations in snow levels. In collection periods one, two, and four, when snow levels

were deep, PIPO consumption was high and GRAG consumption low (Fig. 13). While BERE contributed less to deer diets in 1993, shrubs comprised a larger portion of deer diets in 1993 than in 1992.

Supplemental feeding altered the diet of deer on the Badger study area, thus the hypothesis that supplemental feeding would not alter diet composition was rejected. Despite supplemental feed, Badger deer continued to consume natural forages (Table 8). These results confirm those of Schmitz (1990), who reported that white-tailed deer in Ontario continued to consume natural forages despite "ad libitum" supplementation of corn and oats (Avena sativa). Due to continued consumption of natural forages, Mautz (1978a) cautioned that supplemental feeding may lead to long term habitat degradation.

In the NBH, diet composition differences between supplemented and non-supplemented deer were more evident in the more severe winter of 1993. In 1992, diets of supplemented and non-supplemented deer differed only in the consumption of corn (Table 8). However, in 1993, BERE, GRAG, and FORB were the only forage categories that did not differ (Table 8). The larger dietary difference between supplemented and non-supplemented deer in 1993 may partially be the result of feeding frequency. Supplemental feeding frequency of deer in the NBH is determined based on ambient temperature and snow depth. Deer were fed once per

week in 1992; however, in 1993 supplemental feed was provided three times per week. Diet quality data supported diet composition data, showing a more pronounced difference between supplemented and non-supplemented deer in 1993 (Chapter 3).

As with temporal changes, shifts in important dietary species between years also seemed related to snow depth. In the Black Hills, Hill (1946) estimated that half of the forage consumed by deer in the winter of 1942 would have been covered by one foot of snow under more severe conditions. Diet composition shifts observed during this study are consistent with other published data. With the exception of Burke/Larson, BERE consumption declined among NBH study areas in 1993 when snow pack increased (Table 7). As snow levels increased, BERE also contributed less to the diets of white-tailed deer in southeastern Montana (Dusek 1987) and in the northern Black Hills in 1944 (Harris 1945) and 1967 (Schneeweis 1969).

Dusek (1987) noted that PIPO dominated the winter diets of white-tailed deer when snow covered other forages. In 1993, PIPO consumption rose at Badger, Crow Creek, and Bear Ridge, while the rise at Sleep/Nicholas approached significance. However, PIPO consumption at Burke/Larson did not change (Table 7). Harris (1945) also reported elevated PIPO consumption in the northern Black Hills as

snow levels increased. Thus, the hypothesis the deer diets would be similar between years was rejected.

Diet composition differed among study areas. As a result, the hypothesis that diets would be similar across NBH winter subranges was rejected. Dietary differences among non-supplemented deer were most notable at Burke/Larson and Bear Ridge in 1992, and at Bear Ridge in 1993. Elevated PIPO consumption at Burke/Larson in 1992 (Table 7) may have been the result of logging. Burke/Larson was logged just prior to the start of this study, and as a result, fresh PIPO slash piles were available to deer on this winter subrange but unavailable to deer on other study sites.

The depressed importance of GRAG at Bear Ridge may reflect availability. Topography at Bear Ridge was more rugged (Chapter 2) with fewer grassland openings. Additionally, agricultural fields most accessible to deer at Bear Ridge appeared to be utilized less than agricultural sites on other NBH winter subranges. The low degree of agricultural field - pine/oak (Quercus macrocarpa) draw interspersion, which Kennedy (1992) believed was important for NBH deer, combined with the close proximity to housing may have reduced the attractiveness of these areas to deer.

During 1993, deer at Bear Ridge consumed more SHRUB than deer on Burke/Larson and Crow Creek, however, SHRUB

consumption at Bear Ridge and Sleep/Nicholas was similar (Table 7). Shrub consumption in 1993 also appears to partially reflect availability. Tall shrub and sapling densities were highest on Bear Ridge, followed in descending order by Sleep/Nicholas, Crow Creek, and Burke/Larson (Chapter 2).

Existing data on winter diets of white-tailed deer in the NBH is based on rumen analysis. Differential digestion (Vavra and Holechek 1980) makes comparisons between rumen and fecal analysis difficult. Comparisons are further complicated by potential differences in access to agricultural fields and the combination of grass and agricultural crops into GRAG for this study. However, some generalizations can be drawn about the relative importance of dietary components to deer.

During mild winters, white-tailed deer in the Black Hills rely heavily on low growing forages. During more severe winters, deer consume plant species that are above snow level, but will readily switch to more preferred species as snow levels permit. During the mild winters of 1941 and 1942, the five most important winter forage species were (in declining order of importance) bearberry (Arctostaphylos uva-ursa), BERE, forbs, grain, and grass (Hill 1946). During the more severe winter of 1944 important forages were, PIPO, bearberry, BERE, forbs, and common juniper (Harris 1945). Schneeweis (1969) reported

the most important forages in the mild winter of 1968 were (in descending order) BERE, common juniper, bearberry, grass, and PIPO; however, common juniper, BERE, PIPO, bur oak, and bearberry were the most important in 1967 when snow depth was greater. During this study, the five most important winter forages consumed by white-tailed deer in 1992 (averaged over all collection periods, and reported in descending order) were BERE, GRAG, JUSP, SHRUB, and PIPO. In 1993 the most important winter forages were GRAG, JUSP, SHRUB, PIPO, and BERE.

The most notable differences between historical records and this study are the greater reliance on grasses and agricultural crops and the lack of bearberry in winter diets of NBH deer during this study. In the early 1940's, Hill and Harris (1943), Harris (1945), and Hill (1946) reported NBH deer consumption of GRAG ranged from 5.0 to 14.7%, while bearberry consumption ranged from 17.0 to 32%. In the late 1960's, Schneeweis (1969) reported deer in the NBH consumed 9.8% GRAG and 7.2% bearberry in a mild winter and 10.0% GRAG and 5.3% bearberry in a more severe winter. During the present study GRAG consumption averaged 24.4% in 1992 and 25.4% in 1993, and bearberry never occurred in more than trace amounts. However, bearberry was seldom found on subranges during the present study, and the decreased importance of bearberry to wintering deer may be related to a decline in availability (Chapter 2).

MANAGEMENT IMPLICATIONS

Focusing management efforts on increasing production and/or access to low growing species may be an effective means to improve winter range in the NBH. Habitat improvement in the Black Hills relies primarily on logging. Silvicultural practices can change understory production (Uresk and Severson 1989) and understory quality (Wolters 1973), however, the direction and magnitude of change varies by species (Pase 1958). Although grass and forb production increases as tree canopy cover and basal area decline, some species such as BERE are more abundant in pine stands with intermediate or high canopy cover (Pase 1958). Gibbs (1993) reported non-commercial thinning of PIPO stands in Custer State Park, South Dakota, increased the standing crop biomass of shrubs, grasses, and forbs. However, Bever (1952, as cited by Pase 1958) concluded that after thinning, the principal increase in shrub production comes from parent plants present in the area. Thus the lack of an adequate nearby seed source may limit the rate of reestablishment. Pase (1958) believed that when an adequate seed source was not present, seeding or planting may be needed for maximum gains.

When maintenance of canopy cover is desired, litter reduction may offer an alternative to logging. Understory production declines as litter levels rise (Pase 1958). Prescribed burns conducted in the Black Hills successfully

reduced litter and did not harm pine trees taller than 1.8 m (Gartner and Thompson 1972). Brown and DeByle (1989) noted that BERE responded quickly after fire and increased its proportion of total shrub biomass. Thus prescribed fire may provide an effective means to reduce litter levels and improve understory production on winter range while maintaining hiding/thermal cover for deer.

Fecal analysis can be used to assess temporal fluctuations in diet composition of white-tailed deer over 2 week periods and may provide a means to monitor habitat quality. Except during mild winters, deer will eventually start to consume less palatable forages. If less preferred species are incorporated into the diet early in winter, habitat improvement or herd reduction may be warranted.

Although supplemental feeding will alter winter diets and improve diet quality, it is too expensive to be practiced on a large scale and does relatively little to reduce depredation problems except in the immediate vicinity of feeding stations. Because supplemental feeding will only marginally ease browsing pressure on winter ranges, it does not provide a viable alternative to habitat improvement.

White-tailed deer in the northern Black Hills rely heavily on open grassland/agricultural areas and prefer low growing browse species. As a result, management practices that increase the quality, quantity, and/or availability of

understory vegetation may improve the nutritional condition of deer in the northern Black Hills. During a severe winter, low growing vegetation may be unavailable to deer. Areas selected for improvement should be located where snow levels are likely to be lowest or are likely to recede the fastest.

Chapter 5

Morphological and Physiological Indices to White-tailed Deer Condition in the Northern Black Hills, South Dakota.

INTRODUCTION

White-tailed deer (Odocoileus virginianus dacotensis) condition and health interact with population density through habitat related factors such as forage availability and quality (Kie 1988). Condition indices have been used to assess population health and may be physiological (e.g., blood indices, reproductive rate) or morphological (e.g., body weights, organ weights). Blood indices (Seal et al. 1972, Franzmann and LeResche 1978, and Jenks et al. 1991), body weight (Kie et al. 1983), fat reserves (Finger et al. 1981), and reproductive rate (Verme 1963, 1965, 1967, 1969) have proven useful in monitoring physical and nutritional status of wild ruminants. To be meaningful, condition indices should be collected concurrently with habitat, nutritional, and environmental information, and if possible compared to baseline data for the particular deer herd in question.

Unfortunately, little morphological and physiological data is available for Black Hills deer and few studies have attempted to tie physical and nutrition condition to dietary or habitat characteristics. As a result, baseline values are unavailable for the northern Black Hills (NBH) and interpretation of existing data is difficult.

The primary objective of this study was to evaluate physiological and nutritional condition of white-tailed deer inhabiting five NBH winter subranges to establish

baseline information and determine those physiological and morphological indices related to dietary and habitat characteristics. Coupling this information with diet composition, diet quality, and habitat characteristics may reveal important dietary and/or habitat components necessary for maintaining a healthy and productive deer population in winter. A secondary objective was to determine summer physiological and nutritional condition of deer in the NBH in order to establish baseline data for summer, determine seasonal contrasts, and provide reference values for further research. I hypothesized that deer condition would not vary among NBH subranges, winter condition would not differ from summer condition, and condition of lactating deer would not differ from that of non-lactating female deer.

STUDY AREA

The study was conducted in the northern Black Hills of South Dakota. Five study sites (Fig. 1) totaling 1744 ha were located between Spearfish, South Dakota, and the Wyoming border. Study sites (subranges) were delineated from locations of radio-collared deer (Kennedy 1992). Female deer had high fidelity for these 5 subranges over a two year period. All five are located approximately at 44° 30′ W latitude and range in longitude from 103° 50′ N to 104° 04′ N. Study areas (i.e., Badger [B], Burke/Larson [BL], Crow Creek [CC], Bear Ridge [BR], and Sleep/Nicholas

[SN]) consist of a mixture of federal, state, and private land. A full description of the study area is provided in Chapter 2.

METHODS

Field Methods

Five adult female white-tailed deer were collected from each subrange (i.e., Badger, Burke/Larson, Crow Creek, Bear Ridge, and Sleep/Nicholas) (25 annually, 50 total) in late February/early March 1992 and 1993. An additional 50 (25 annually) adult female white-tailed deer were collected during late August 1992 and 1993. Deer were head-shot in morning/evening using a high powered rifle. Immediately after the animal dropped, blood samples were collected via heart puncture in Vacutainer (Becton Dickinson, Rutherford, New Jersey 07070, USA) serum and whole blood collection tubes. Animals that were not cleanly killed and thus were active (struggled or ran) prior to death were considered "stressed". All blood samples were placed on ice until processed. Live and eviscerated weights were recorded to the nearest pound. Fetus(es), kidneys with all perirenal fat, adrenal glands, spleen, intestinal/rectal feces, femur, and both lower incisors were collected and stored frozen until processed.

Analytical Methods

Blood Indices---Sera was separated within 7 hours of collection and samples were stored frozen until analyzed.

The degree of hemolysis (lysis of red blood cells) was categorized as described in Blankenship and Varner (1978) (i.e., none, slight, moderate, or heavy). Serum samples were analyzed by the South Dakota State University Veterinary Sciences Diagnostic Laboratory. Urea nitrogen, phosphorus, total protein, and glucose levels were determined by colorimetric analyses using Sigma (Sigma Diagnostics, St. Louis, Missouri, 63178, USA) kits 640-A, 670-A, 541-2, and 315-100, respectively and following procedures recommended by the manufacturer. Potassium and sodium levels were determined using a flame photometer (Faulkner and Meites 1982).

Packed cell volume levels were determined from whole blood samples using the microcapillary method (Ravel 1989); the remaining sample was stored frozen. Glycosylated hemoglobin levels were later determined from whole blood using a Pierce GlycoTest II, GlyHb assay Kit 44120 (Pierce, Rockford, Illinois 61105, USA) following the procedures recommended by the manufacturer.

Morphological and Physiological Indices---Reproductive rate was determined from fetal counts (Hesselton and Sauer 1973). Fetuses were measured as described by Cheatum and Morton (1946) and aged using the regression equation provided by Hamilton et al. (1985). Fat reserves of female deer were determined using kidney fat indices (total perirenal [Monson et al. 1974] and Riney [Riney 1955 as

cited by Monson et al. 1974] methods). Femur marrow fat was determined via the ovendrying method of Neiland (1970). Age was determined by the South Dakota Department of Game, Fish, and Parks from counts of cementum annuli (Gilbert 1966, Rice 1976). Spleens and paired adrenal gland weights were recorded to the nearest 0.1 g.

Statistical Methods

Probability plots and Bartlett's tests were used to evaluate normality and homogeneity assumptions, respectively; non-normal or heterogeneous data were rank transformed (Conover and Iman 1981). The level for statistical significance was set at $P \leq 0.05$. Analysis of covariance was used to test if hemolysis or stress affected blood indices. Analysis of covariance also was used to test morphological, physiological, and blood indices for main and interactive effects of study area and year. Total body weight and date of collection were used as covariates except when analyzing body weight, in which case age and date of collection were used as covariates. Analysis of variance was used to test an *a priori* hypothesis that supplementally fed deer did not differ from non-supplemented deer. A Tukey's HSD was used when significant differences existed among study areas. SYSTAT (Wilkinson 1990) was used to perform all statistical analyses.

RESULTS

Blood Indices

Four animals were not cleanly killed and were classified as "stressed" for the purposes of blood analyses. Forty-nine serum samples were not hemolyzed. Twenty-four, 7, and 4 serum samples were categorized as slightly, moderately, or heavily hemolyzed, respectively. Summer 1993 hemolysis data were unavailable because serum samples were discarded before degree of hemolysis was recorded. Neither stress nor hemolysis affected blood urea nitrogen (stress, F = 2.402, 1 df, P = 0.124; hemolysis, F = 2.391, 3 df, P = 0.076), phosphorus (stress, F = 1.355, 1 df, P = 0.0.247; hemolysis, F = 0.490, 3 df, P = 0.690), potassium (stress, F = 0.548, 1 df, P = 0.461; hemolysis, F = 2.138, 3 df, P = 0.0.103), sodium (stress, F = 0.084, 1 df, P = 0.773; hemolysis, F = 0.279, 3 df, F = 0.841), glucose (stress, F = 1.467, 1 df, P = 0.229; hemolysis, F = 0.427, 3 df, P = 0.735), total protein (stress, F = 0.719, 1 df, P = 0.398; hemolysis, F = 2.273, 3 df, P = 0.088), and packed cell volume (stress, F = 0.360, 1 df, P = 0.550; hemolysis, F = 0.249, 2 df, P = 0.781).

Winter glucose (Appendix 4) and glycosylated hemoglobin (Appendix 4)) levels did not vary with area (F = 0.172, 4 df, P = 0.952 and F = 1.620, 4 df, P = 0.188, respectively) or year (F = 0.010, 1 df, P = 0.920 and F = 1.513, 1 df, P = 0.226, respectively). Although winter

glucose levels fell within the range for undrugged deer reported by Seal et al. (1981) (Fig. 14), winter glycosylated hemoglobin levels were lower than those reported by Jenks et al. (1991) (Fig. 15). Glucose levels were higher (F = 5.009, 1 df, P = 0.028) in winter than summer (Table 9) and glycosylated hemoglobin decreased (F = 7.765, 1 df, P = 0.008) as collection date increased. Although phosphorus levels did not vary among sites (F = 1.379, 4 df, P = 0.259) or between years (F = 2.109, 1 df, P = 0.154) (Appendix 4), they were higher (F = 70.279, 1 df, P < 0.001) in summer than winter (Table 9) and were within the reference range reported by Seal et al. (1981) (Fig. 16).

Winter potassium levels were higher (F = 5.033, 1 df, P = 0.030) in 1992 than in 1993 (Appendix 4) and were above the reference values reported by Seal et al. (1981) in both years (Fig. 17). Total protein also was higher (F = 9.955, 1 df, P = 0.003) in 1992 than in 1993 (Appendix 4) and was within the reference range reported (Seal et al. 1981) (Fig. 18). Additionally, both potassium and total protein were higher (F = 46.541, 1 df, P < 0.001 and F = 16.696, 1 df, P < 0.001) in summer than winter (Table 9).

An area by year interaction (F = 7.897, 1 df, P < 0.001) occurred for sodium. As a result, years were analyzed separately. Sodium levels were lower in 1993 than in 1992 at Badger (F = 24.881, 1 df, P < 0.001), Crow Creek

(F = 8.937, 1 df, P = 0.005), Bear Ridge (F = 5.451, 1 df, P = 0.025), and Sleep/Nicholas (F = 35.920, 1 df, P < 0.001) (Appendix 4). However, sodium concentrations were higher (F = 4.922, 1 df, P = 0.033) in 1993 at Burke/Larson (Appendix 4). Sodium concentrations did not vary (F = 0.267, 1 df, P = 0.607) with season (Table 9). All sodium levels were within the reference range reported by Seal et al. (1981) (Fig. 19).

Contrary to other blood indices, packed cell volume (PCV) levels were higher (F = 6.612, 1 df, P = 0.014) in 1993 than in 1992 (Appendix 4) and were higher (F = 7.525, 1 df, P = 0.007) in winter than summer (Table 9) but were within reference values reported by Seal et al. (1981) (Fig. 20). Packed cell volume also declined (F = 8.386, 1 df, P = 0.006) as collection date increased and was higher (F = 10.239, 1 df, P = 0.003) in non-lactating than in lactating deer (Table 10).

Although, blood urea nitrogen (BUN) did not vary between winters (F = 0.414, 1 df, P = 0.524) (Appendix 4) it was within the reported reference range (Seal et al. 1981) (Fig. 21) and was the only blood index found to vary (F = 9.550, 4 df, P < 0.001) among study areas (Appendix 4). Badger and Burke/Larson had higher (Tukey's HSD = 29.581, 40 df, P > 0.05) BUN levels than Bear Ridge and Sleep/Nicholas; Crow Creek was similar to all study areas. Additionally, supplementally fed deer had higher (F =

5.700, 1 df, P = 0.022) BUN levels than their non-supplemented counterparts (Appendix 4). Blood urea nitrogen concentrations were higher (F = 23.289, 1 df, P < 0.001) in winter than summer (Table 9). Lactation had no effect (F = 1.386, 1 df, P = 0.245) on BUN levels (Table 10).

A weak but significant relationship existed between BUN and fecal nitrogen levels determined from intestinal feces. In 1992, 43.8% of the variation in BUN was explained by fecal nitrogen (F = 16.370, 1 df, P = 0.001) (Fig. 22a). In 1993, the relationship was not as strong (r^2 = 22.6%, F = 6.718, 1 df, P = 0.016) (Fig. 22b).

Morphological and Physiological Indices

Generally, morphological and physiological indices were more strongly affected by total body weight and collection date than were blood indices, but they were useful for detecting differences between seasons, years, and lactational status. Spleen weight did not differ among study areas (Appendix 5) and was higher (F = 6.513, 1 df, P = 0.012) in summer than winter (Table 11).

Paired adrenal gland weight did not vary among study areas (F = 1.041, 4 df, P = 0.399) (Appendix 5) or between years (F = 0.084, 1 df, P = 0.774) (Appendix 5), but increased with total body weight (F = 11.995, 1 df, P = 0.001) and also increased as collection date advanced (F = 4.008, 1 df, P = 0.052). In winter, average adrenal gland

weight was higher (F = 17.438, 1 df, P < 0.001) than the average summer weight (Table 11). Additionally, lactating deer in the NBH had heavier (F = 16.325, 1 df, P < 0.001) adrenal glands than non-lactating deer (Table 12).

Neither total body weight (Appendix 5) nor eviscerated weight (Appendix 5) varied among study areas (F = 0.575, 4 df, P = 0.683 and F = 0.304, 4 df, P = 0.874, respectively [Appendix 5]) or between years (F = 0.221, 1 df, P = 0.641 and F = 0.124, 1 df, P = 0.726, respectively [Appendix 5]). Total body weight increased (F = 9.531, 1 df, P = 0.011) with age, was lower (F = 134.802, 1 df, P < 0.001) in winter than summer (Table 11), and lactating deer were heavier (F = 43.737, 1 df, P < 0.001) than non-lactating deer (Table 12).

Eviscerated weight declined (F = 5.824, 1 df, P = 0.020) as collection date advanced. Although NBH deer had a higher (F = 52.617, 1 df, P < 0.001) average eviscerated weight in summer than winter (Table 11), there was no difference (F = 1.763, 1 df, P = 0.070) between lactating and non-lactating deer (Table 12).

Age of deer did not vary among study areas (F = 2.301, 4 df, P = 0.075) (Appendix 5) or between years (F = 0.198, 1 df, P = 0.659) (Appendix 5) but did increase (F = 9.531, 1 df, P = 0.004) as total weight increased. Additionally, deer collected in winter were older (on average) (F = 35.284, 1 DF, P < 0.001) than deer collected in summer

(Table 11) and lactating deer were older (on average) (F = 4.977, 1 df, P = 0.031) than non-lactating deer (Table 12).

Total kidney fat indices (T-KFI) declined as collection date advanced (F = 7.135, 1 df, P = 0.011). Although T-KFI did not vary among winter subranges (F = 0.187, 4 df, P = 0.944) (Fig. 23) or between years (F = 0.026, 1 df, P = 0.872) (Appendix 5), T-KFI levels were greater (F = 14.307, 1 df, P < 0.001) in summer than winter (Table 11). Lactating deer also had lower (F = 51.357, 1 df, P < 0.001) T-KFI values than non-lactating deer (Table 12).

Riney kidney fat indices (R-KFI) also declined as collection date progressed (F = 6.906, 1 df, P = 0.012). Riney kidney fat indices did not differ among winter subranges (Fig. 24) but were higher (F = 5.850, 1 df, P = 0.020) in 1992 than in 1993 (Appendix 5). Riney kidney fat indices also were lower (F = 7.745, 1 df, P = 0.007) in winter than summer (Table 11) and lactating deer had lower (F = 47.792, 1 df, P < 0.001) R-KFI than non-lactating deer (Table 12).

Like T-KFI and R-KFI, femur marrow fat declined as collection date advanced (F = 9.542, 1 df, P = 0.004) but did not differ among study areas (Fig. 25). Among winter subranges, femur marrow fat reserves were lower (F = 25.754, 1 df, P < 0.001) in 1993 than in 1992 (Appendix 5). However, unlike T-KFI and R-KFI, marrow fat showed did not

change with season (F = 0.545, 1 df, P = 0.462) (Table 11) or lactational status (F = 1.328, 1 df, P = 0.255) (Table 12).

Reproductive rate increased (F = 8.954, 1 df, P = 0.005) with total body weight. Although, both reproduction and conception dates responded to winter severity (Appendix 5), neither varied among study area (Fig. 26 and Fig. 27, respectively). Fetuses per doe increased (F = 6.610, 1 df, P = 0.014) from 1992 to 1993 (Appendix 5). Average date of conception differed (F = 24.666, 1 df, P < 0.001) by one week, occurring on 2 December (Julian date 337.4 ± 1.4) in 1992 and 26 November (Julian date 329.6 ± 1.3) in 1993 (Appendix 5). Conception date varied but did not differ (F = 1.289, 1 df, P = 0.263) with age (Fig. 28).

DISCUSSION

Blood Indices

Stress associated with physical handling (Seal et al. 1972, Seal et al. 1981), activity/struggling prior to death (Blankenship and Varner 1978), or capture (DelGiudice et al. 1990) can affect blood indices. Stress did not appear to affect blood indices during the present study. Blankenship and Varner (1978) discovered that the degree of hemolysis affected blood indices, however, the magnitude of change varied by index. Although most blood indices were unaffected except at the highest level of hemolysis, glucose concentrations were altered by slight hemolysis

(Blankenship and Varner 1978). Contrary to the findings of Blankenship and Varner, hemolysis did not appear to affect blood indices in the present study, however, it is possible that hemolysis contributed to the variability observed in glucose data.

Blood indices have proven useful indicators of nutritional and physical condition, but may vary with time of day (Kirkpatrick 1980) and age (Seal et al. 1981). Fawn hematologic values change as they grow (Rawson et al. 1992) but approach adult levels by 3-4 months (Seal et al. 1981). Blood index differences between sexes also have been noted (Anderson and Medin 1972, Blankenship and Varner 1978), with the most prominent differences being associated with rutting (Franzmann and LeResche 1978) and pregnancy (Kie et al. 1983). However, most hematologic values are not significantly affected by sex (White and Cook 1974, Kie et al. 1983). Because only adult female white-tailed deer were collected during the present study, sex and age variation were considered minimal.

Seal et al. (1981) cautioned that each population should be compared to its own unique set of "reference values." Unfortunately, reference values do not exist for Black Hills deer; however, with the exception of potassium, all blood indices evaluated in the present study were within reference ranges for non-drugged deer reported by Seal et al. (1981).

Glucose is the main energy compound for cells (Franzmann and LeResche 1978). Glucose levels were shown to increase with improved condition among adult moose (Franzmann et al. 1976). However, glucose levels may vary erratically and show no intra (this study) (Fig. 14) or interseasonal trends (Seal et al. 1972, Waid and Warren 1984). Jenks et al. (1991) proposed glycosylated hemoglobin as a long term indicator of glucose status. During the current study, glycosylated hemoglobin fluctuated less than glucose, but showed no trends (Fig. 15). Average glycosylated hemoglobin levels for NBH deer (1.9 ± 0.055 % in 1992 and 1.806 ± 0.053 % in 1993) were lower than late winter (i.e., 6 March to 21 March) (2.5 ± 0.1 %) and summer (i.e., August) (3.7 ± 0.4 %) averages reported for captive white-tailed deer maintained on a high protein diet and wild white-tailed deer, respectively (Jenks et al. 1991).

Like glucose and glycosylated hemoglobin, blood phosphorus concentrations did not distinguish between study areas or years (Fig. 15). Other blood indices analyzed were more sensitive to changes in nutritional condition and varied with year (i.e., sodium, potassium, PCV, and total protein) or study area (BUN). Serum electrolytes (i.e., sodium and potassium) indicated poorer condition in the winter of 1993 than in 1992. Sodium levels declined from 1992 to 1993. Sodium levels for deer collected at

Burke/Larson in 1992 were far below those for other subherds. Additionally, Burke/Larson was the only study area where sodium levels were higher in 1993 than they were in 1992 (Fig. 19).

Like sodium, blood potassium levels also declined (P = 0.030) during 1993. Potassium was the only blood index that did not fall within the reference range reported by Seal et al. (1981) (Fig. 17). Potassium levels for NBH deer averaged 7.89 ± 0.27 mEq/L, which was about twice the 4.2 mEq/L average reported by Seal et al. (1981). However, Anderson and Medin (1972) and White and Cook (1974) have reported potassium level averages of 8.18 mEq/L and 6.8 mEq/L, respectively. Nevertheless, the potassium concentrations reported in the present study may have been influenced by the length of time between death and serum acquisition (Weeks 1974). "Permeability of cell walls change and active transport systems cease to function at death or shortly thereafter. At this time passive movement of potassium ions from the high intracellular concentration in red blood cells to the serum undoubtedly begins" (Weeks 1974:312). As a result, the potassium concentrations reported in the current study may not reflect the potassium concentrations in a living animal.

Franzmann and LeResche (1978) concluded that PCV was perhaps one of the most useful condition indicators. Packed cell volume levels increase as animal condition

improves (Franzmann and LeResche 1978) and Bahnak et al. (1979) reported captive deer on better quality diets had higher PCV levels. Packed cell volume was less useful for NBH deer; although differences existed between years, it was not possible to distinguish among study areas. As a result of hemoconcentration, PCV levels are higher in winter and decline during spring and summer (Bahnak et al. 1979) when the moisture content of vegetation is higher and more free water is available. During the current study, PCV levels were higher ($P = 0.014$) in winter 1993, which may be the result of dehydration (DelGiudice and Seal 1988). Packed cell volume levels declined ($P = 0.006$) as collection date increased, and may reflect the physiological transition from winter to spring. Additionally, PCV was the only index that detected differences between lactating and non-lactating deer. However, supplemental feeding had no effect on PCV. Although fecal nitrogen and phosphorus indicated Badger deer were consuming a higher quality diet (chapter 3), PCV levels tended to indicate poorer condition (Fig. 20).

Total protein may decline in cases of chronic protein deficiency (LeResche et al. 1974) and is generally depressed only in cases of extreme distress. Among moose, total protein levels were higher in summer than winter and probably reflected changes in dietary protein consumption (LeResche et al. 1974). The results of the current study

supported findings of LeResche et al. (1974); total protein levels for NBH deer indicated that protein availability declined from 1992 to 1993 and also declined from summer to winter. However, supplemental feeding in the NBH had no effect on total protein. Bahnak et al. (1979) reported diet quality did not affect TP levels except during lactation, but, TP levels in the NBH did not respond to lactation.

Blood urea nitrogen is generally considered an indicator of dietary protein intake (Verme and Ullrey 1984) and also has been correlated with ruminal nitrogen (Klinger et al. 1986) and deer density (Kie et al. 1983). During the present study, BUN was the only blood index that detected effects of supplemental feeding (Appendix 4; Fig. 21). These results are similar to those of Seal et al. (1972) and Bahnak et al. (1979) who both reported that captive white-tailed deer consuming high quality diets had elevated BUN concentrations.

However, BUN concentrations must be interpreted with care. Although, BUN concentrations rise as protein intake rises, low energy (Kirkpatrick et al. 1975) and poor quality (deCalesta et al. 1975, Bahnak et al. 1979) diets also elevate BUN. Hebert (1978) demonstrated that when bighorn sheep were fed diets above protein maintenance levels, high BUN concentrations were associated with good condition; however, when diets were below protein

maintenance levels, muscle tissue was catabolized, elevating BUN and indicating poor condition. Tissue catabolism may explain why BUN levels were higher in winter than in summer in the NBH.

Kirkpatrick (1980) suggested that BUN was potentially useful as a condition indicator but should be assessed along with other corroborating evidence. Hebert (1978) recommended using BUN in conjunction with fecal nitrogen to assess protein status and condition. The relationship between fecal nitrogen and BUN (i.e., regression slopes and intercepts) in the NBH was similar in 1992 and 1993 (Fig. 22), suggesting variation may be due to winter severity. As a result, fecal nitrogen data may be useful to clarify protein status among NBH deer.

Following the recommendations of Hebert (1978), fecal nitrogen was used to assess protein status and BUN levels were re-evaluated relative to fecal nitrogen levels. Both fecal nitrogen (Chapter 3) and BUN (Appendix 4) concentrations indicated that supplemented deer consumed diets higher in protein than non-supplemented deer. However, while fecal nitrogen concentrations indicated that supplemented deer tended (difference approached significance) to consume better quality (i.e., more protein) diets in 1993 and non-supplemented deer consumed poorer quality diets in 1993 (Chapter 3), BUN levels (Appendix 4) revealed no difference in diet quality. Lower

protein diets in the more severe winter of 1993 is supported by lower total serum protein levels (Appendix 4) in 1993.

The failure of BUN to detect diet quality differences between years may be related to winter severity and whether deer were above or below protein maintenance levels. The poorer correlation between fecal nitrogen and BUN concentrations in 1993 (Fig. 22b) may indicate that more deer were below protein maintenance thresholds. Thus, fecal nitrogen can be used to assess diet quality whether deer are above or below protein maintenance, and may be a better method to access dietary protein consumption.

Morphological and Physiological Indices

Although social stress caused by high population density may enlarge spleen weights (Aiton 1938, Christian et al. 1959), wide fluctuations (Anderson et al. 1974, this study) lessen the value of spleen weight as an indicator of condition. Adrenal gland weight also will increase in response to elevations in stress level (Christian et al. 1960, Welch 1962, Christian and Davis 1964), however under controlled experimental conditions, Seal et al. (1983), were unable to find evidence suggesting adrenal size was affected by population density. According to Selye's (1946) general adaption syndrome, the ability to detect adrenal enlargement may depend upon the duration of the stress period. In the initial phase (stage of alarm) of

the general adaption syndrome, adrenal glands enlarge; in the stage of resistance (phase II) adrenal enlargement is less noticeable; in the stage of exhaustion (phase III), adrenal glands again enlarge (Selye 1946). Adrenal gland weights in NBH deer did not differ among study areas despite differences in deer density.

Weeks (1974) reported adrenal gland weights among female white-tailed deer in Indiana were highest from April through June and he believed the stress of pregnancy and lactation were partially responsible for the peak in adrenal gland weight during this season. In the NBH, adrenal gland weights were larger in lactating than in non-lactating deer (Table 12), possibly indicating the stress associated with the nutritional demands of lactation. Adrenal gland weight was higher in winter than summer (Table 11). Additionally, winter adrenal gland weights were similar to adrenal gland weights of lactating deer, which may indicate greater stress levels during winter than summer.

Total and eviscerated weights were not useful intraseasonal condition indicators for NBH deer. However, body weight has been related to range condition (Kie et al. 1984), diet quality (Seal et al. 1972), age (this study), and reproductive rate (this study). Additionally, both total and eviscerated weight were higher during summer (Table 11) and among lactating deer (Table 12). Although

body weights were not sensitive enough to detect subtle intraseasonal differences, they were useful when trying to contrast the prominent differences associated with winter vs. summer and lactating vs. non-lactating female deer.

Deer collected in winter were older (on average) than deer collected in summer (Table 11). This probably represents a sampling bias. Because males did not have antlers during winter collections (February) and distinguishing sex was difficult, deer were collected by shooting female deer that had fawns. Because deer in the NBH do not breed until they are relatively old (discussed below), the winter sample was skewed towards older animals. As a result the summer collection was probably more representative of the age structure of NBH deer.

For deer in the NBH, R-KFI's were better condition indicators than kidney fat indices using all perirenal fat (i.e., T-KFI). The latter fluctuated widely and were not useful for detecting differences among study areas or between years (Fig. 23). These results are contrary to the findings of Monson et al. (1978).

Although kidney fat reserves were reduced on all study areas in 1993, those of supplementally fed deer did not decline to the degree of non-supplemented areas. As fat reserves are depleted, marrow fat is mobilized (Hesselton and Sauer 1973) and KFI's are no longer an accurate measure of physical condition (Ransom 1965). Ransom (1965)

determined that femur marrow fat utilization began at 30% R-KFI, and that below that point, KFI values are not accurate predictors of deer condition. However, Kie et al. (1983) contend that marrow fat utilization does not begin until 15% R-KFI.

Using the more conservative threshold of 30%, NBH deer R-KFI levels did not drop below that level during 1992 (Fig. 24), thus deer presumably did not rely on marrow fat reserves. This is supported by the higher levels of femur fat in 1992 (Appendix 5). However, 1993 R-KFI levels showed Badger deer to be in relatively good condition compared to non-supplemented areas, which were slightly below the 30% threshold (Fig. 24). In 1993, marrow fat reserves were lower across all study areas (Appendix 5). However, Mech and DelGiudice (1985) cautioned that high levels of femur fat do not necessarily imply good condition. Femur fat is the last fat store utilized prior to starvation. Therefore, any use of marrow fat probably indicates poor condition.

When considered simultaneously, R-KFI and marrow fat indicated that NBH deer were able to maintain body condition during a mild winter. During the more severe winter of 1993, non-supplemented deer had lower fat reserves than in 1992.

Unusually low femur marrow fat levels among deer at Burke/Larson (Fig. 25) may be the result of habitat

differences. Kennedy (1992) reported that NBH deer preferred areas which provided thermal cover. Burke/Larson is strongly divided into agricultural and forested habitat types (Chapter 2). Logging could have reduced the thermal cover value of the forested portion which would in turn increase the amount of energy deer had to expend for thermoregulation. Results of the present study seem to support the findings of Kennedy (1992); thermal cover is an important component of winter range in the NBH.

Reproductive rate is a useful measure of condition (Kie 1988). Although NBH reproductive rates are considerably below the maximum for white-tailed deer (Roseberry and Klimstra 1070) and are lower than for other parts of South Dakota (McPhillips 1990), they are comparable with reproduction observed in similar habitats (Mundinger 1981). Unless habitat and diet quality are ideal, females that successfully produced fawns the previous year may not reach reproductive status by the next breeding season (Verme 1967). Mundinger (1981) reported alternate year breeding among white-tailed deer in the coniferous forests of northwestern Montana. The rise in NBH reproductive rate from 1992 (1.16 fetuses/doe) to 1993 (1.58 fetuses/doe) could represent alternate year breeding, but also partly reflects the mild winter and early greenup that occurred in 1992. Robinette and Gashwiler (1955) believed winter famine inhibits the fertility of yearling

female deer because food eaten in other seasons is used primarily for weight recovery rather than sexual development. Because NBH deer emerged from the 1992 winter in better condition, more deer may have been able to reach reproductive status during the following breeding season.

Body weight (Hesselton and Sauer 1973) and physiological status (Mueller and Sadleir 1979, as cited by Verme and Ullrey 1984), rather than age, determine when a deer is capable of breeding. When consuming good quality diets fawns may reach reproductive status late in the breeding season (Haugen 1975, Nixon et al. 1991). During the current study no fawns were collected in winter, however, 1 year old animals that were collected during summer (i.e., fawns during the previous breeding season) were not lactating; thus NBH fawns do not appear to reach reproductive status. Mundinger (1981) reported that yearlings rather than fawns comprised the youngest breeding class in Swan Valley, Montana, and indicated inadequate range condition may have been responsible for poor reproduction.

Julander et al. (1961) reported that productivity among the youngest breeding age class reflected range condition more sensitively than productivity of older deer. Diet quality affected how quickly fawns reached puberty (Abler et al. 1976), and on submarginal range it is not uncommon for yearlings to remain sexually immature (Verme

and Ullrey 1984). No winter collected NBH yearlings were pregnant and only 43% of the previous years yearlings were lactating in summer. Data from this study indicated that most NBH deer do not breed until 2.5 years of age.

Over the two years of this study the breeding season in the NBH ranged from 20 November to 24 December and is within the time frame reported for white-tailed deer in New York (27 October to 18 January with peak breeding occurring 10-23 November [Cheatum and Morton 1946]), Michigan (5 November to 15 December, peak breeding date 17 November [Verme 1969]), and Montana (12 November to 28 December [Dusek et al. 1989]). The 1992 breeding season in the NBH ran 29 days, while the 1993 breeding season ran 15 days. Dusek et al. (1989) reported that 95% of female white-tailed deer along the Yellowstone river in Montana conceived during the first estrus cycle. Assuming a 4 week interval between estrus cycles (Cheatum and Morton 1946), most breeding in the NBH also occurs during the first cycle. However, there is evidence that older deer may be breeding later in the season than younger animals.

To determine fawn mortality rate in the NBH, fawns were captured and radio-collared (Benzon 1994). Two peaks occurred in fawn captures (by researchers); the first around 13 June (Benzon 1994) and a second, smaller peak about 10 days later (T. A. Benzon, S.D. Dept. Game, Fish and Parks, unpubl. data). Assuming a 200 day gestation

length (Cheatum and Morton 1946), deer collected in winter would have given birth around 15 June, which corresponds well with the first peak reported by Benzon (1994). However, if conception dates are averaged by age, younger females (approximately 2.5 to 5.5 years) had a tendency to breed slightly earlier than older females (6.5+ years) (Fig. 28), which may account for the second peak observed by Benzon (T. A. Benzon, S.D. Dept. Game, Fish and Parks, unpubl. data). The second peak also could have resulted from animals that were not bred until the second estrus. Late fawning may adversely affect NBH fawn survival. Clutton-Brock et al. (1987) discovered that summer and winter mortality of red deer (Cervus elaphus) calves increased with each day the calf was born past the median calving date. Further, the number of late born calves dying in summer, winter, and as yearlings increased with population density (Clutton-Brock et al. 1987).

MANAGEMENT IMPLICATIONS

Kie et al. (1983) cautioned against using a single index to determine deer condition, especially if dealing with small sample sizes. During this study, some indices were not useful for differentiating between winter subranges or years (e.g., glucose, total and eviscerated weight, T-KFI, and age), others did not allow differentiation, but did show trends (e.g., phosphorus). Although total protein, sodium, potassium, PCV, R-KFI,

femur marrow, and reproductive rate all showed differences between years, and BUN showed differences among study areas, interpreting each index individually often led to contradicting conclusions.

Dinkines et al. (1991) believed condition profiles for assessing habitat quality based on several indices should prove more sensitive in the presence of interfering variables. When NBH ranges were evaluated using all condition indices, deeper, more persistent snow resulted in poorer condition in 1993, and despite higher densities, deer receiving supplemental feed were in better condition than non-supplemented animals during both years. Non-supplemented winter subranges were able to meet deer nutritional requirements in the mild winter, but non-supplemented deer relied partially on body reserves in the harsher winter of 1993.

Although supplemental feeding improved deer condition, it is impractical on a large scale. Options to improve white-tailed deer condition in the NBH include reducing the population and improving the habitat. Population reductions will require extensive public relation efforts to gain acceptance. Logging is widely used in the NBH as a tool to improve habitat, however, prescribed burning may also be effective. Because much of the NBH winter range lies on private land, both options will require state and federal agencies to work closely with landowners.

Additionally, many NBH communities are growing. During spring 1992, Spearfish, South Dakota, annexed 81 ha (200 acres) of rural land to accommodate expected population growth. As urbanization continues, it will become increasingly important to ensure remaining NBH winter range is capable of meeting the nutritional demands of white-tailed deer.

Morphological/physiological indices were more useful for detecting condition differences among white-tailed deer than were blood indices. Several morphological/ physiological and blood indices changed as collection date advanced. Therefore, collection periods should be as brief as possible to minimize temporal influence. Using multiple indices to determine deer condition will improve the ability to interpret data and reduce the chance of drawing incorrect conclusions.

Riney kidney fat indices were the most useful morphological/physiological index; however, total body weight, age, femur marrow, and reproductive data also provides valuable information about deer condition. Packed cell volume, the most useful blood index, requires little specialized equipment, no specialized training, and may be the only blood index practical for management agencies with limited laboratory facilities.

CHAPTER 6

Project Summary

WINTER SUBRANGES

Principal component analysis revealed overstory factors (i.e., total canopy cover, basal area, litter, and tall shrub/sapling density) explained 51.38% of the variation among white-tailed deer (Odocoileus virginianus) winter subranges in the northern Black Hills (NBH), South Dakota. Winter subranges were separated into two categories: 1) ponderosa pine (Pinus ponderosa) dominated, forested areas (i.e., Badger and Bear Ridge) and 2) agricultural areas (i.e., Burke/Larson, Crow Creek, and Sleep/Nicholas). Additionally, to reduce depredation to local ranchers, South Dakota Department of Game, Fish and Parks supplements some herds by planting food plots and distributing alfalfa (Medicago sativa) and corn (Zea mays) during winter. As a result, subranges also were separated into supplemented (i.e., Badger) and non-supplemented (i.e., Burke/Larson, Crow Creek, Bear Ridge, and Sleep/Nicholas) ranges.

The winter of 1992 was unusually mild with minimal snowpack which occurred in early January. Snow rarely covered the ground for more than 2 or 3 days at a time in 1992. The winter of 1993 was more severe. Below normal temperatures in January and February 1993 resulted in deeper, more persistent snow across all study areas. In 1993, snow was present in shaded areas and draws into March.

Diet quality improved as the 1992 season advanced, fecal nitrogen and phosphorus levels in late March were higher than the previous five collection periods. However, in 1993, fecal indices did not improve significantly from early January to late March but did display mid-winter fluctuations similar to those observed with diet composition.

Supplemental feeding at Badger resulted in higher levels of fecal nitrogen (2.0%) and phosphorus (0.56%) than non-supplemented subranges (1.6% and 0.34%, respectively). Additionally, the pattern of change between years at Badger differed from the pattern observed on non-supplemented subranges. In 1993, fecal nitrogen and phosphorus concentrations on non-supplemented areas were similar or lower than they had been in 1992. In contrast, fecal nitrogen and phosphorus levels at Badger were slightly higher in 1993 than they had been in 1992. Feeding frequency, which is based on temperature and snow depth may offer a partial explanation. In 1992, deer were fed once per week, however, during the more severe winter of 1993, feeding frequency increased to three times per week.

Fecal indices indicated non-supplemented deer consumed higher quality diets in 1992 than in 1993. Fecal nitrogen declined from 1.6 ± 0.05% in 1992 to 1.5 ± 0.05% in 1993 while fecal phosphorus levels declined from 0.32 ± 0.03% to 0.30 ± 0.03% in 1992 and 1993, respectively. Deer at

Burke/Larson and Crow Creek consumed higher quality diets than deer at Bear Ridge and Sleep/Nicholas. Although diet quality did not differ between Bear Ridge and Sleep/Nicholas, deer densities at Bear Ridge were half the densities observed at other non-supplemented areas, indicating Bear Ridge was capable of supporting fewer deer.

Thirteen browse species (i.e., trees and shrubs), two agricultural species, 15 grasses, 10 forbs, and 12 unknowns were identified from fecal samples in this study. However, only 3 individual (Oregon grape (Berberis repens), ponderosa pine, and juniper (Juniperus spp.) consistently accounted for $\geq$ 5% of the diet. Plant species were combined into 8 forage categories to reduce the number of variables and aid interpretation. Ponderosa pine (PIPO), Oregon grape (BERE), juniper spp. (JUSP), collective shrubs (SHRUB), collective grasses and agricultural crops (GRAG), collective forbs (FORB), corn, and collective unknowns (UNK) composed the 8 categories examined.

Dietary composition shifts between years were related to snow depth. Intraseasonal dietary changes in 1992 were gradual and may reflect a transition from a winter to a spring diet. Deer consumption of BERE was higher in early January (48.29%) than it was in early March (17.75%). In contrast, GRAG comprised a larger portion of the diet in early March (40.61%) than early January (12.03%). Temporal changes in 1993 also display a transition from a winter to

a spring diet, however, the progression was not as smooth apparently due to mid-winter fluctuations in snow depth. Ponderosa pine consumption was higher in early January (30.51%) than late March (8.27%), while GRAG contributed more to deer diets in late March (41.56%) and early January (6.98%). Mid-winter diet composition fluctuations in 1993 were probably the result of 20.3-30.5 cm (8-12 inches) of snow that fell over a 6 day period in mid-February, covering low growing vegetation.

Deeper, more persistent snow in 1993 also altered important dietary components. Low growing forages such GRAG (24.21%) and BERE (35.85%) were the primary dietary components in 1992. In 1993, across all winter subranges except Burke/Larson, BERE consumption decreased to 8.90% and PIPO consumption (which had been 6.21% in 1992) rose to 18.12%. The importance of GRAG to deer was undiminished in 1993 (25.43%) because GRAG becomes most important to deer in March when snow levels have receded and vegetation begins to green.

In 1992, corn was present in the diets of supplemented deer (1.6%) but it was not found in the diets of non-supplemented animals. No other forage categories differed between supplemented and ncn-supplemented deer. However, in 1993 the diets of supplemented and non-supplemented deer were less similar. Grass/agricultural crops was the only forage category that did not differ. Deer at Badger

consumed less PIPO (11.9%), JUSP (11.2%), and SHRUB (9.3%) than non-supplemented deer (19.7%, 21.1%, and 20.7%, respectively). Supplemented deer also consumed more BERE (10.9%), FORB (4.4%), and corn (15.3%) than non-supplemented deer (8.4%, 1.7%, and 0.8%).

Serum potassium levels were 8.32 mEq/L in 1992 and 7.46 mEq/L in 1993. Total protein was 6.13 g/dl in 1992 and 5.70 g/dl in 1993, likely reflecting lower protein availability in 1993. Higher packed cell volume levels in 1993 (49.05%) compared to 1992 (46.26%) may have resulted from dehydration in 1993. Across all study areas, lower Riney kidney fat indices and femur marrow fat values in 1993 (34.71% and 72.71%, respectively) compared to 1992 (54.82% and 88.42%, respectively) indicated deer relied more heavily on fat reserves during the more severe winter.

Dinkines et al. (1991) believed condition profiles for assessing habitat quality based on several indices should prove more sensitive in the presence of interfering variables. During the present study, interpreting each index individually often led to contradictory conclusions. When NBH ranges were evaluated using all condition indices, deeper, more persistent snow resulted in poorer condition in 1993. Despite higher densities, deer receiving supplemental feed were in better condition than non-supplemented animals during both years. Among non-

supplemented subranges, deer on agricultural areas tended to be in better condition than those on forested areas.

Supplemental feeding improved deer condition but is impractical on a large scale. Because supplemental feeding will only marginally ease browsing pressure on winter ranges it does not provide a viable alternative to habitat improvement. Options for improving deer diet quality and condition include population reduction and habitat improvement. Population reductions will require extensive public relation efforts to gain public acceptance and may not be effective due to possible competition from cattle and a small, but growing elk (Cervus elaphus) population in the NBH. Logging is widely used in the NBH as a tool to improve habitat, however, prescribed burning may also be effective, particularly if management goals are to reduce litter levels and improve understory production on winter range while maintaining hiding/thermal cover for deer.

SEASONAL COMPARISONS (i.e., SUMMER vs. WINTER)

Despite numerous physiological and behavioral adaptations that help deer survive winter, most deaths of adult deer (in northern latitudes) occur during this season (Mautz 1978a). Leslie et al. (1984) determined that diet quality was highest in spring and lowest in winter. The results from the northern Black Hills also indicate that deer are in better condition in summer. Higher phosphorus, potassium, total protein, and lower blood urea nitrogen

during summer indicated improved condition. Although glucose levels declined from 160.29 mg/dl in winter to 144.44 mg/dl in summer, indicating poorer condition, wide fluctuations in glucose levels reduce its effectiveness as a condition index. Higher adrenal gland weights in winter (3.75 g) than summer (2.84 g) may indicate deer were under more stress in winter. Spleen weights (also a stress indicator) were higher in summer (143.16 g) than winter (133.16 g), contradicting adrenal gland data. However, spleen weights fluctuated widely and may be less reliable than adrenal gland weights. Total body weight was higher in summer (55.80 kg) than winter (45.80 kg). Additionally, Riney kidney fat indices were higher in summer (71.32%) than winter (42.13%).

EFFECTS OF LACTATION ON DEER NUTRITIONAL STATUS

Nursing female deer are under appreciable nutritional stress, and even a well fed doe will lose weight when lactating (Verme and Ullrey 1984). In the NBH, lactating deer were older (5.88 years) and weighed (total body weight) more (58.49 kg) than non-lactating deer (3.75 years and 51.37 kg, respectively). Paired adrenal gland weight was greater in lactating deer (3.68 g) than non-lactating deer (2.45 g) and may reflect the nutritional and physiological stress associated with lactation. Additionally, non-lactating animals had higher Riney kidney fat indices (129.17%) than lactating deer (32.32%). Packed

cell volume, the only blood index to differ between lactating (42.95%) and non-lactating (47.22%) deer, also indicated poorer condition among lactating animals.

Body weight (Hesselton and Sauer 1973) and physiological status (Mueller and Sadleir 1979, as cited by Verme and Ullrey 1984) determine when a deer is capable of breeding. Reproductive potential among white-tailed deer reaches its maximum in prime age (generally 3-7 years) females (Verme and Ullrey 1984). However, data from the present study indicated that most NBH deer do not produce fawns until 2.5 years of age and the average age of lactating deer is skewed toward older animals, both of which may be a reflection of habitat condition. On submarginal range it is not uncommon for yearlings to be sexually immature (Verme and Ullrey 1984).

Diet quality is important on a year-round basis (Mautz 1978b). Autumn nutrition strongly affects reproductive rate (Verme 1967). The spring/summer period of 1993 was cooler than normal with above average precipitation, which may account for elevated fat reserves observed in deer collected in the summer of 1993. Among lactating deer, Riney kidney fat indices increased from 19.74% in 1992 to 44.90% in 1993, while Riney kidney fat indices of non-lactating deer increased from 110.53% in 1992 to 147.81% in 1993. Fat reserves accumulated during fall may improve winter survival of deer (Hobbs 1989). Because deer in the

NBH are migratory, it is essential to monitor habitat quality on winter, summer, and transition ranges in the NBH.

FUTURE RESEARCH NEEDS

Agricultural land was largely responsible for maintaining the deer population in the NBH. However, deer in many parts of the Black Hills do not have access to agricultural land. Additional research is needed to determine which habitat or dietary components influence the nutritional status of deer with limited access to cultivated land.

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Table 1. Habitat characteristics (mean [$\bar{x}$] ± 1 standard error [S.E.]) of winter subranges in the northern Black Hills, South Dakota.

	Coniferous Cover (%)		Deciduous Cover (%)		Total Cover (%)		Average DBH (cm)		Basal Area (m^2/ha)		Total tall shrub/sapling (shrubs/40-m^2)	
Study area	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.
Badger	33.56	2.02^{A1}	2.94	1.06^{AB}	36.13	2.20^{A}	10.68	0.58^{A}	51.92	3.75^{A}	9.36	1.18^{A}
Burke/Larson	6.35	2.01^{B}	3.48	1.05^{AB}	9.83	2.20^{B}	3.04	0.58^{D}	11.50	3.73^{B}	1.43	1.18^{C}
Crow Creek	14.99	2.01^{C}	2.80	1.05^{B}	17.79	2.20^{C}	5.22	0.58^{C}	27.20	3.73^{C}	2.81	1.18^{CD}
Bear Ridge	28.72	2.01^{A}	2.97	1.06^{AB}	31.66	2.20^{A}	7.70	0.58^{B}	40.15	3.73^{A}	12.11	1.18^{B}
Sleep/Nicholas	10.77	2.02^{BC}	5.00	1.06^{A}	15.60	2.20^{BC}	4.23	0.58^{CD}	26.80	3.73^{BC}	6.17	1.18^{D}

[1]Within habitat characteristics, study areas sharing ≥ one letter are not significantly different ($P > 0.05$).

Table 2. Ground cover (%) by average Daubenmire mid-point class (mean [$\bar{x}$] ± 1 standard error [S.E.]) of winter subranges in the northern Black Hills, South Dakota.

Study Area	Grass $\bar{x}$ (S.E.)	Forb $\bar{x}$ (S.E.)	Agricultural $\bar{x}$ (S.E.)	Bare Soil $\bar{x}$ (S.E.)	Litter $\bar{x}$ (S.E.)	Rock $\bar{x}$ (S.E.)	Slash $\bar{x}$ (S.E.)	Oregon grape $\bar{x}$ (S.E.)	Common juniper $\bar{x}$ (S.E.)	Horizontal juniper $\bar{x}$ (S.E.)
Badger	19.4 (2.2)^{B1}	2.6 (0.2)^{AB}	2.8 (0.2)^{A}	5.2 (1.3)^{A}	56.5 (3.0)^{A}	2.5 (0.4)^{A}	2.6 (0.3)^{A}	3.0 (0.2)^{A}	2.6 (0.1)^{A}	4.6 (0.3)^{A}
Burke/Larson	34.3 (2.2)^{A}	2.8 (0.2)^{AB}	2.9 (0.2)^{A}	13.0 (1.3)^{B}	30.5 (3.0)^{B}	3.2 (0.4)^{A}	2.5 (0.3)^{A}	3.0 (0.2)^{A}	2.5 (0.1)^{A}	2.5 (0.3)^{B}
Crow Creek	28.5 (2.2)^{AC}	3.3 (0.2)^{A}	2.5 (0.2)^{A}	9.1 (1.3)^{C}	38.9 (3.0)^{B}	4.6 (0.4)^{A}	2.6 (0.3)^{A}	2.8 (0.2)^{A}	2.5 (0.1)^{A}	2.6 (0.3)^{B}
Bear Ridge	11.2 (2.2)^{D}	2.5 (0.2)^{B}	2.5 (0.2)^{A}	5.0 (1.3)^{AC}	53.6 (3.0)^{A}	3.3 (0.4)^{A}	4.1 (0.3)^{B}	2.5 (0.2)^{A}	2.6 (0.1)^{A}	2.5 (0.3)^{B}
Sleep/Nicholas	23.0 (2.2)^{BC}	2.6 (0.2)^{AB}	2.8 (0.2)^{A}	8.4 (1.3)^{AC}	32.1 (3.0)^{B}	3.5 (0.4)^{A}	2.6 (0.3)^{A}	2.5 (0.2)^{A}	2.5 (0.1)^{A}	2.5 (0.3)^{B}

[1]Within ground cover categories, study areas sharing ≥ one letter are not significantly different ($P > 0.05$).

Table 3. Shrub frequency (%) for winter subranges in the northern Black Hills, South Dakota.

Study area	PIPO[1]	PRSPP	AMSPP	SYSPP	ROSPP	QUMA	RHGL	AMCA	CHSPP	ARFR	RHAR	RISPP	OSVI	Study area $\bar{x}$
Badger	34.0	53.0	53.0	65.0	32.0	53.0	2.0	20.0	8.0	10.0	1.0	7.0	13.0	27.0
Burke/Larson	5.0	10.0	9.0	25.0	14.0	11.0	0.0	8.0	19.0	23.0	0.0	6.0	9.0	10.7
Crow Creek	4.0	13.0	6.0	18.0	17.0	11.0	13.0	28.0	33.0	25.0	0.0	7.0	11.0	14.3
Bear Ridge	23.0	57.0	56.0	67.0	40.0	62.0	1.0	34.0	13.0	13.0	6.0	11.0	16.0	30.7
Sleep/Nicholas	4.0	35.0	19.0	28.0	52.0	36.0	3.0	36.0	42.0	39.0	2.0	10.0	6.0	24.0

[1]PIPO = ponderosa pine (Pinus ponderosa); PRSPP = chokecherry (Prunus spp.); AMSPP = serviceberry (Amelanchier spp.); SYSPP = snowberry (Symphoricarpos spp.); ROSPP = rose (Rosa spp.); QUMA = bur oak (Quercus macrocarpa); RHGL = smooth sumac (Rhus glabra); AMCA = leadplant (Amorpha canescens); CHSPP = rabbitbrush (Chrysothamnus spp.); ARFR = fringed sagebrush (Artemisia frigida); RHTR = skunkbrush sumac (Rhus aromatica); RISPP = gooseberry (Ribes spp.); OSVI = ironwood (Ostrya virginiana).

Table 4. Factor loadings from principal component analysis of habitat variables in the northern Black Hills, South Dakota.

Variable	Factor 1	Factor 2	Factor 3
Total cover[1]	0.949	0.015	0.103
Basal area	0.912	-0.031	0.104
Litter	0.820	0.149	0.180
Tall shrub/sapling	0.813	0.071	0.093
Bare soil	-0.530	0.333	0.776
Distance to edge	0.012	0.950	-0.305
% Variance[2]	51.380	16.803	17.617

[1]Total cover = coniferous canopy cover + deciduous canopy cover
[2]Total sample variance explained by each factor.

Table 5. Fecal nitrogen and phosphorus levels (%) of study area composites and individual deer collected from the northern Black Hills, South Dakota, 1992 and 1993.

	Study Area Composite				Individual Deer			
	1992		1993		1992		1993	
Study Area	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Fecal Nitrogen								
Badger	1.937	0.066	2.038	0.066	2.152	0.108	2.026	0.108
Burke/Larson	1.795	0.066	1.650	0.066	1.928	0.121	1.696	0.108
Crow Creek	1.677	0.066	1.602	0.066	1.832	0.108	1.706	0.108
Bear Ridge	1.607	0.066	1.415	0.066	1.503	0.121	1.400	0.108
Sleep/Nicholas	1.662	0.066	1.488	0.066	1.646	0.108	1.416	0.108
Average	1.735	0.018	1.639	0.018	1.812	0.051	1.649	0.048
Fecal Phosphorus								
Badger	0.503	0.043	0.597	0.043	0.614	0.065	0.442	0.065
Burke/Larson	0.421	0.043	0.358	0.043	0.550	0.073	0.419	0.065
Crow Creek	0.392	0.043	0.332	0.043	0.429	0.065	0.347	0.065
Bear Ridge	0.347	0.043	0.253	0.043	0.313	0.073	0.303	0.065
Sleep/Nicholas	0.324	0.043	0.260	0.043	0.276	0.065	0.277	0.065
Average	0.397	0.011	0.360	0.011	0.436	0.031	0.357	0.029

Table 6. Fecal nitrogen (%) and phosphorus (%) levels of supplemented and non-supplemented deer in the northern Black Hills, South Dakota, 1992 and 1993.

Study Area	1992 $\bar{x}$	1992 SE	1993 $\bar{x}$	1993 SE	Significance
Fecal Nitrogen					
Supplemented[1]					
Badger	1.888	0.049	2.038	0.045	0.058
Non-supplemented[2]					
Burke/Larson	1.698^{A}	0.049	1.650^{a}	0.045	0.029
Crow Creek	1.616^{AB}	0.049	1.602^{ac}	0.045	0.029
Bear Ridge	1.524^{B}	0.049	1.415^{b}	0.045	0.029
Sleep/Nicholas	1.610^{AB}	0.049	1.488^{bc}	0.045	0.029
Average	1.612	0.049	1.539	0.045	-----
Fecal Phosphorus					
Supplemented[1]					
Badger	0.457	0.029	0.597	0.026	0.113
Non-supplemented[2]					
Burke/Larson	0.352^{A}	0.029	0.358^{a}	0.026	0.049
Crow Creek	0.349^{A}	0.029	0.332^{a}	0.026	0.049
Bear Ridge	0.296^{B}	0.029	0.253^{b}	0.026	0.049
Sleep/Nicholas	0.289^{B}	0.029	0.260^{b}	0.026	0.049
Average	0.322	0.029	0.301	0.026	-----

[1]Supplemented deer had higher ($P \leq 0.001$) fecal indices than non-supplemented deer during both 1992 and 1993.

[2]Non-supplemented study areas sharing $\geq$ one letter are not significantly different ($P \leq 0.05$). Differences within 1992 and 1993 are denoted with upper and lower case letters, respectively.

Table 7. Diet composition (% cover) (mean ± [1 standard error]) of non-supplemented white-tailed deer in the northern Black Hills, South Dakota, January-March 1992 and 1993.

Study Area	Forage Component							
	Ponderosa Pine[1]	Oregon Grape[1]	Juniper Spp.[2]	Shrubs	Grass/ Agricultural	Forbs	Corn[1]	Unknown[1]
1992								
BL[3]	16.4 (2.1)	19.6 (3.5)	18.5 (2.4)	9.5 (2.4)	24.4 (4.3)	3.0 (1.0)	0.0 (0.0)	8.7 (0.9)*
CC	2.1 (2.1)*	34.1 (3.5)*	20.4 (2.4)	9.3 (2.4)	29.5 (4.3)	2.9 (1.0)	0.0 (0.0)	1.8 (0.9)
BR	3.0 (2.1)*	52.0 (3.5)*	16.6 (2.4)	12.8 (2.4)*	9.9 (4.3)	2.5 (1.0)	0.0 (0.0)	3.2 (0.9)
SN	6.5 (2.1)	36.0 (3.5)*	4.8 (2.4)*	17.0 (2.4)	26.6 (4.3)	4.1 (1.0)	0.0 (0.0)	4.9 (0.9)*
$\bar{x}$	7.0 (2.1)	35.4 (3.5)	15.1 (2.4)	12.2 (2.4)**	22.6 (4.3)	3.1 (1.0)**	0.0 (0.0)	4.6 (0.9)
1993								
BL[3]	21.0 (3.1)	10.3 (1.7)	21.7 (3.7)	9.0 (2.8)	31.7 (5.3)	2.3 (0.5)	0.0 (0.8)	4.0 (0.8)*
CC	22.0 (3.1)*	9.2 (1.7)*	26.3 (3.7)	16.0 (2.8)	20.4 (5.3)	0.9 (0.5)	3.0 (0.8)	2.7 (0.8)
BR	23.1 (3.1)*	10.0 (1.7)*	13.5 (3.7)	31.8 (2.8)*	17.0 (5.3)	1.3 (0.5)	0.0 (0.8)	3.4 (0.8)
SN	12.7 (3.1)	4.0 (1.7)*	23.0 (3.7)*	26.0 (2.8)	30.6 (5.3)	2.1 (0.5)	0.1 (0.8)	1.6 (0.8)*
$\bar{x}$	19.7 (3.1)	8.4 (1.7)	21.1 (3.7)	20.7 (2.8)**	24.9 (5.3)	1.6 (0.5**	0.7 (0.8)	2.9 (0.8)

Table 7. Cont.

Study Area	Forage Component							
	Ponderosa Pine[1]	Oregon Grape[1]	Juniper Spp.[2]	Shrubs	Grass/ Agricultural	Forbs	Corn[1]	Unknown[1]
Overall average: 1992 and 1993								
BL[3,4]	18.9 (3.5)^{A}	14.6 (5.8)^{A}	20.2 (3.0)^{A}	9.3 (2.7)^{A}	28.4 (5.1)^{A}	2.6 (0.6)^{A}	0.0 (0.5)^{A}	6.1 (0.7)^{A}
CC	12.6 (3.5)^{B}	20.5 (5.8)^{A}	23.6 (3.0)^{A}	13.0 (2.7)^{AB}	24.5 (5.1)^{A}	1.8 (0.6)^{A}	1.6 (0.5)^{A}	2.3 (0.7)^{B}
BR	13.9 (3.5)^{AB}	29.1 (5.8)^{A}	14.9 (3.0)^{A}	23.2 (2.7)^{B}	13.8 (5.1)^{A}	1.8 (0.6)^{A}	0.0 (0.5)^{A}	3.3 (0.7)^{AB}
SN	9.9 (3.5)^{AB}	18.6 (5.8)^{A}	14.7 (3.0)^{A}	21.9 (2.7)^{B}	28.8 (5.1)^{A}	3.1 (0.6)^{A}	0.0 (0.5)^{A}	3.1 (0.7)^{AB}
$\bar{x}$	13.8 (3.5)	20.7 (5.8)	18.4 (3.0)	16.9 (2.7)	23.9 (5.1)	2.3 (0.6)	0.4 (0.5)	3.7 (0.7)

[1]Due to area by year interactions ($P \leq 0.05$), years were analyzed separately. As a result, differences between subranges may not represent the trends that occurred within years.
[2]Juniperus communis and J. horizontalis were indistinguishable in deer diets.
[3]BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.
[4]Within a forage class, study areas sharing ≥ one letter are not significantly different ($P \geq 0.05$).
*Within a study area, the amount of the forage class consumed differed ($P \leq 0.05$) between 1992 and 1993.
**Forage class consumption differed ($P \leq 0.05$) between 1992 and 1993.

Table 8. Dietary composition (% cover) of supplemented and non-supplemented white-tailed deer in the northern Black Hills, South Dakota, January-March, 1992 and 1993.

Forage Component	Supplemented $\bar{x}$	Supplemented S.E.	Non-supplemented $\bar{x}$	Non-supplemented S.E.	Significance
1992					
Ponderosa pine[1]	3.1	1.9	7.0	2.1	0.080
Juniper spp.[1]	10.0	2.2	15.1	2.4	0.113
Shrubs[1]	11.9	2.3	12.2	2.4	0.988
Corn[1]	1.6	0.5	0.0	0.0	< 0.001
Unknowns[1]	0.6	0.8	4.6	0.9	0.001
1993					
Ponderosa pine[1]	11.9	2.8	19.7	3.1	0.003
Juniper spp.[1]	11.2	3.6	21.1	3.7	0.034
Shrub[1]	9.3	2.7	20.7	2.8	0.001
Corn[1]	15.3	1.6	0.8	0.8	< 0.001
Unknowns[1]	9.6	2.0	2.9	0.8	0.025
Average: 1992 and 1993					
Oregon grape	23.0	5.6	20.7	5.8	0.319
Grass/Agricultural	29.4	4.7	23.9	5.1	0.136
Forb	4.1	0.7	2.3	0.6	0.055

[1]Due to area by year interactions ($P \leq 0.05$), years were analyzed separately.

Table 9. Blood indices of white-tailed deer collected in winter and summer from the northern Black Hills, South Dakota, 1992 and 1993.

Index	Winter $\bar{x}$	Winter (SE)	Summer $\bar{x}$	Summer (SE)	Significance
Glucose (mg/dl)					
1992	159.92	12.96	141.56	12.36	0.218
1993	160.66	12.67	147.33	12.69	0.098
$\bar{x}$	160.29	9.64	144.44	9.40	0.028
Phosphorus (mg/dl)					
1992	7.11	0.32	9.66	0.31	< 0.001
1993	6.58	0.32	10.55	0.32	< 0.001
$\bar{x}$	6.84	0.24	10.10	0.24	< 0.001
Potassium (mEq/l)					
1992	8.24	0.32	9.93	0.31	< 0.001
1993	7.35	0.32	9.93	0.32	< 0.001
$\bar{x}$	7.80	0.24	9.93	0.24	< 0.001
Total Protein (g/dl)					
1992	6.24	0.12	6.60	0.11	0.026
1993	5.82	0.11	6.48	0.11	0.001
$\bar{x}$	6.03	0.09	6.54	0.08	< 0.001
Sodium (mEq/l)					
1992	148.83	1.44	140.14	1.38	0.016
1993	138.87	1.41	143.81	1.41	0.178
$\bar{x}$	143.85	1.07	141.97	1.05	0.267

Table 9. Cont.

Index	Winter $\bar{x}$	Winter (SE)	Summer $\bar{x}$	Summer (SE)	Significance
Packed Cell Volume (%)					
1992	46.30	0.93	44.76	0.86	0.140
1993	49.10	0.93	43.93	0.89	0.072
$\bar{x}$	47.70	0.70	44.35	0.65	0.007
Blood Urea Nitrogen (mg/dl)					
1992	24.17	1.27	15.26	1.21	< 0.001
1993	25.05	1.24	19.03	1.24	0.008
$\bar{x}$	24.61	0.94	17.15	0.92	< 0.001

Table 10. Blood indices of lactating and non-lactating female white-tailed deer, collected from the northern Black Hills, South Dakota, February 1992 and 1993.

Index	Lactating		Non-lactating		Signif-icance
	$\bar{x}$	(SE)	$\bar{x}$	(SE)	
Glucose[1] (mg/dl)					
1992	143.52	21.06	161.51	23.38	0.473
1993	146.61	16.07	128.89	25.03	0.432
$\bar{x}$	145.07	13.62	145.20	18.13	0.640
Phosphorus[2] (mg/dl)					
1992	8.40	0.50	10.20	0.56	0.155
1993	10.06	0.38	10.23	0.60	0.460
$\bar{x}$	9.23	0.32	10.22	0.432	0.194
Potassium (mEq/l)					
1992	9.73	0.51	10.03	0.56	0.112
1993	10.00	0.39	9.41	0.60	0.523
$\bar{x}$	9.86	0.33	9.72	0.44	0.294
Total Protein (g/dl)					
1992	6.81	0.18	6.64	0.20	0.867
1993	6.57	0.13	6.63	0.21	0.797
$\bar{x}$	6.69	0.11	6.63	0.15	0.888
Sodium[2] (mEq/l)					
1992	139.62	1.70	138.98	1.89	0.365
1993	144.87	1.30	144.83	2.02	0.245
$\bar{x}$	142.24	1.10	141.91	46	0.987

Table 10. Cont.

Index	Lactating $\bar{x}$	(SE)	Non-lactating $\bar{x}$	(SE)	Signif-icance
Packed Cell Volume (%)					
1992	43.18	1.26	46.49	1.40	0.400
1993	42.73	0.96	47.95	1.50	0.003
$\bar{x}$	42.95	0.81	47.22	1.08	0.003
Blood Urea Nitrogen[2] (mg/dl)					
1992	14.52	1.20	16.63	1.32	0.295
1993	18.44	0.91	19.80	1.41	0.203
$\bar{x}$	16.48	0.77	18.22	1.02	0.245

[1]Index was lower ($P < 0.05$) during 1993.
[2]Index was higher ($P < 0.05$) during 1993.

Table 11. Morphological and physiological indices of white-tailed deer collected in winter and summer from the northern Black Hills, South Dakota, 1992 and 1993.

Index	Winter $\bar{x}$	Winter (SE)	Summer $\bar{x}$	Summer (SE)	Significance
Spleen (g)					
1992	136.33	8.95	144.19	8.54	0.024
1993	129.99	8.75	142.13	8.77	0.621
$\bar{x}$	133.16	6.66	143.16	6.49	0.012
Paired Adrenal Gland Weight (g)					
1992	3.73	0.19	2.81	0.18	0.002
1993	3.76	0.19	2.86	0.19	0.031
$\bar{x}$	3.75	0.144	2.84	0.14	< 0.001
Total Body Weight (Kg)					
1992	46.03	1.09	55.46	1.04	< 0.001
1993	45.57	1.04	56.14	1.04	< 0.001
$\bar{x}$	45.80	0.75	55.80	0.74	< 0.001
Eviscerated Weight (Kg)					
1992	33.92	0.86	39.12	0.82	< 0.001
1993	33.74	0.82	38.72	0.82	< 0.001
$\bar{x}$	33.83	0.60	38.92	0.58	< 0.001
Age					
1992	7.02	0.57	3.98	0.54	< 0.001
1993	7.13	0.55	3.97	0.56	0.003
$\bar{x}$	7.07	0.42	3.97	0.41	< 0.001

Table 11. Cont.

Index	Winter $\bar{x}$	Winter (SE)	Summer $\bar{x}$	Summer (SE)	Significance
Total Kidney Fat Index (%)					
1992	64.54	19.53	131.13	18.58	0.006
1993	62.40	19.44	172.64	19.07	0.107
$\bar{x}$	63.47	14.66	151.89	14.12	< 0.001
Riney Kidney Fat Index (%)					
1992	51.82	9.35	65.39	8.89	0.136
1993	32.44	9.30	77.25	9.13	0.094
$\bar{x}$	42.13	7.01	71.32	6.75	0.007
Femur Marrow (%)					
1992	90.90	2.93	82.61	2.79	0.023
1993	75.62	2.86	82.20	2.86	0.206
$\bar{x}$	83.26	2.18	82.41	2.12	0.462

Table 12. Morphological and physiological indices of lactating and non-lactating female white-tailed deer, collected from the northern Black Hills, South Dakota, February 1992 and 1993.

Index	Lactating $\bar{x}$	Lactating (SE)	Non-lactating $\bar{x}$	Non-lactating (SE)	Signif-icance
Spleen (g)					
1992	125.42	14.31	177.78	15.90	0.093
1993	157.49	10.92	161.29	17.02	0.248
$\bar{x}$	141.45	9.26	169.54	12.33	0.288
Paired Adrenal Gland Weight (g)					
1992	3.82	0.25	2.62	0.28	0.080
1993	3.54	0.19	2.27	0.30	0.003
$\bar{x}$	3.68	0.16	2.45	0.22	< 0.001
Total Body Weight (Kg)					
1992	60.67	1.55	48.88	1.66	< 0.001
1993	56.31	1.32	53.86	2.09	< 0.001
$\bar{x}$	58.49	1.04	51.37	1.41	< 0.001
Eviscerated Weight (Kg)					
1992	36.87	0.79	41.72	0.87	0.175
1993	37.76	0.60	39.67	0.94	0.391
$\bar{x}$	37.32	0.51	40.69	0.68	0.070
Age					
1992	5.98	0.83	4.04	0.92	0.312
1993	5.77	0.63	3.45	0.98	0.108
$\bar{x}$	5.88	0.54	3.75	0.71	0.030

Table 12. Cont.

Index	Lactating $\bar{x}$	Lactating (SE)	Non-lactating $\bar{x}$	Non-lactating (SE)	Significance
Total Kidney Fat Index[1] (%)					
1992	34.46	23.62	222.76	26.24	0.001
1993	92.64	18.03	342.16	28.08	< 0.001
$\bar{x}$	63.55	15.28	282.46	20.34	< 0.001
Riney Kidney Fat Index[1] (%)					
1992	19.74	11.11	110.53	12.34	< 0.001
1993	44.90	8.48	147.81	13.21	< 0.001
$\bar{x}$	32.32	7.19	129.17	9.57	< 0.001
Femur Marrow (%)					
1992	86.67	3.37	85.93	3.74	0.900
1993	84.89	2.57	80.50	4.01	0.325
$\bar{x}$	85.78	2.18	83.21	2.90	0.255

[1]Index was higher ($P < 0.05$) during 1993.

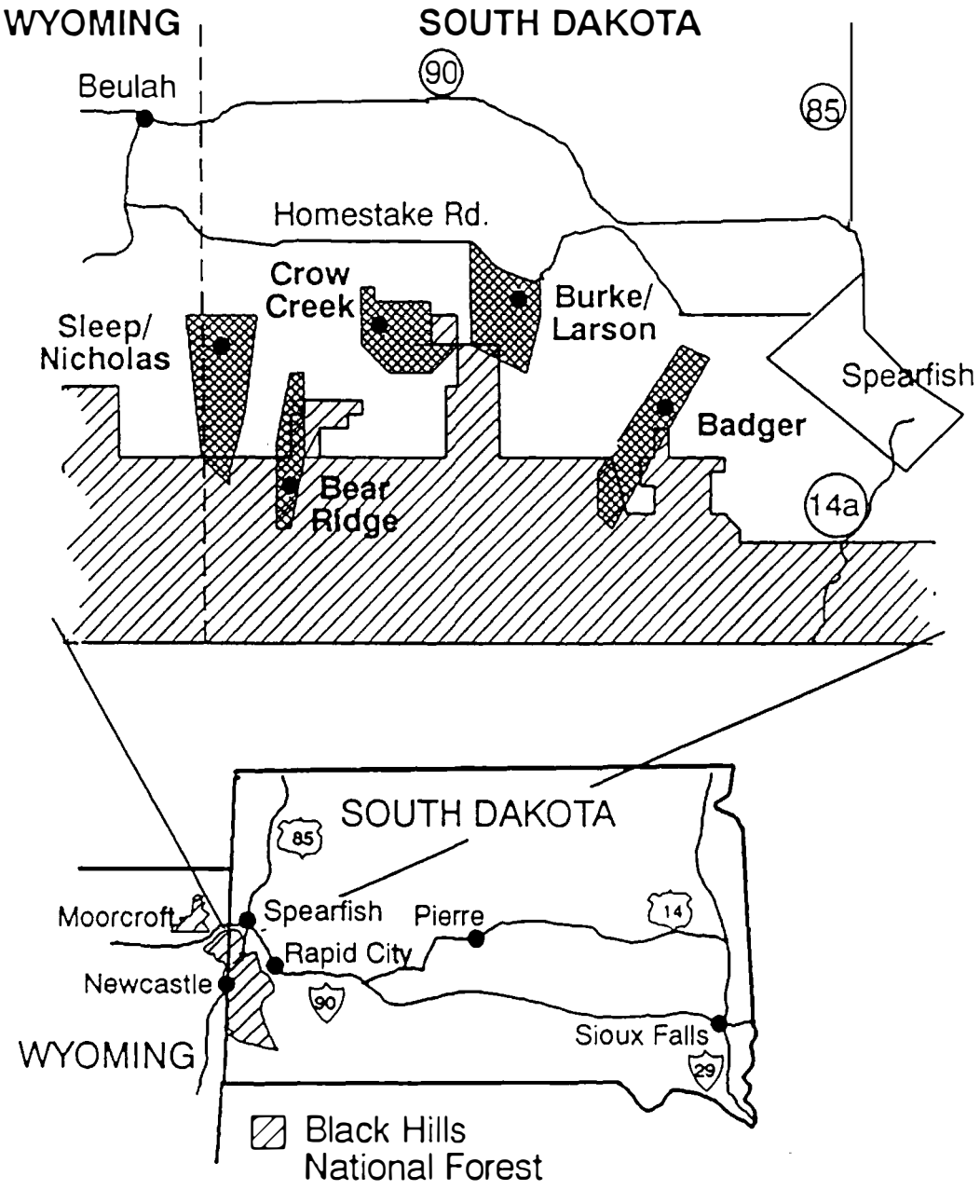

Figure 1. Location of the study area in the northern Black Hills, South Dakota and Wyoming.

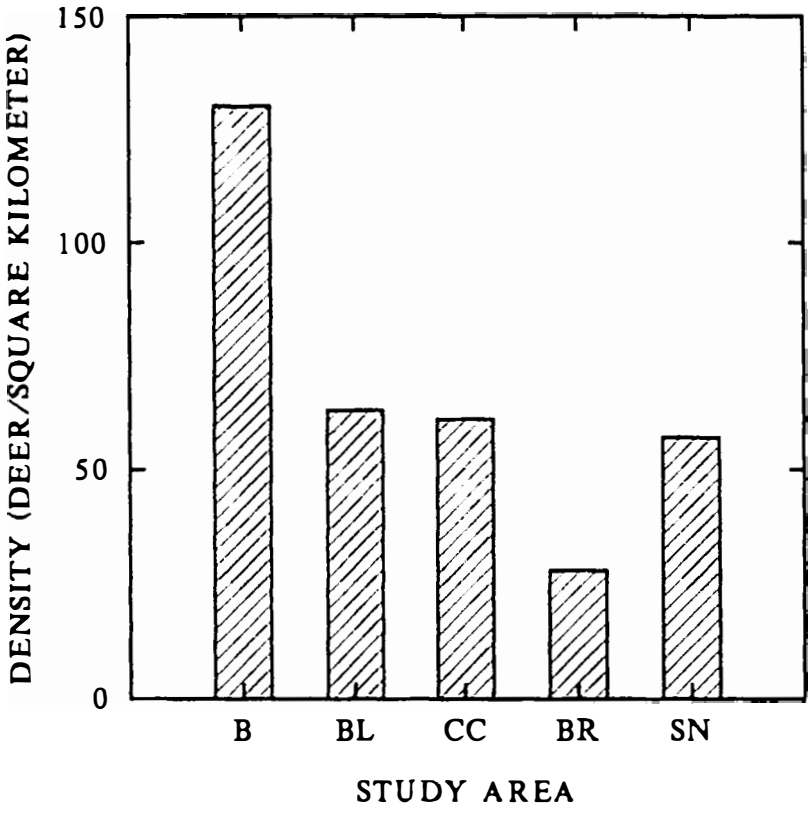

Figure 2. Deer density estimates of winter subranges in the northern Black Hills, South Dakota, 1992 (based on track count data).
B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

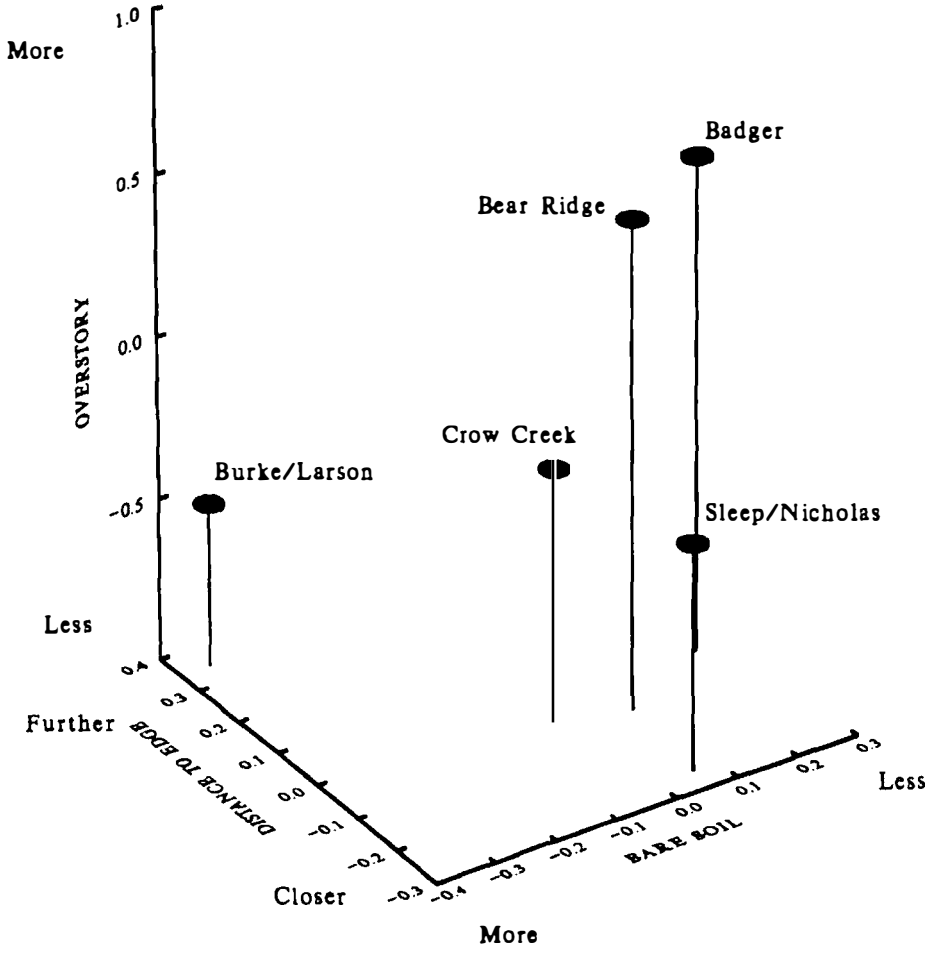

Figure 3. Principal component factors for winter subranges of white-tailed deer in the northern Black Hills, South Dakota, based on principal component analysis.

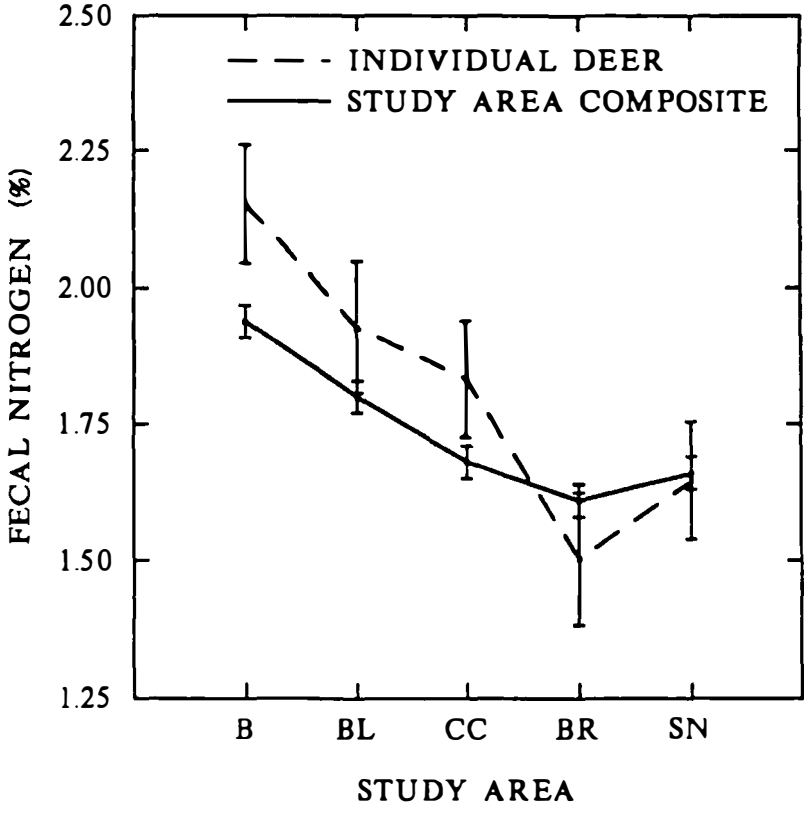

Figure 4. Average fecal nitrogen values (± one standard error) for study area composites and indivual deer collected from the northern Black Hills. South Dakota. 1992.
B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

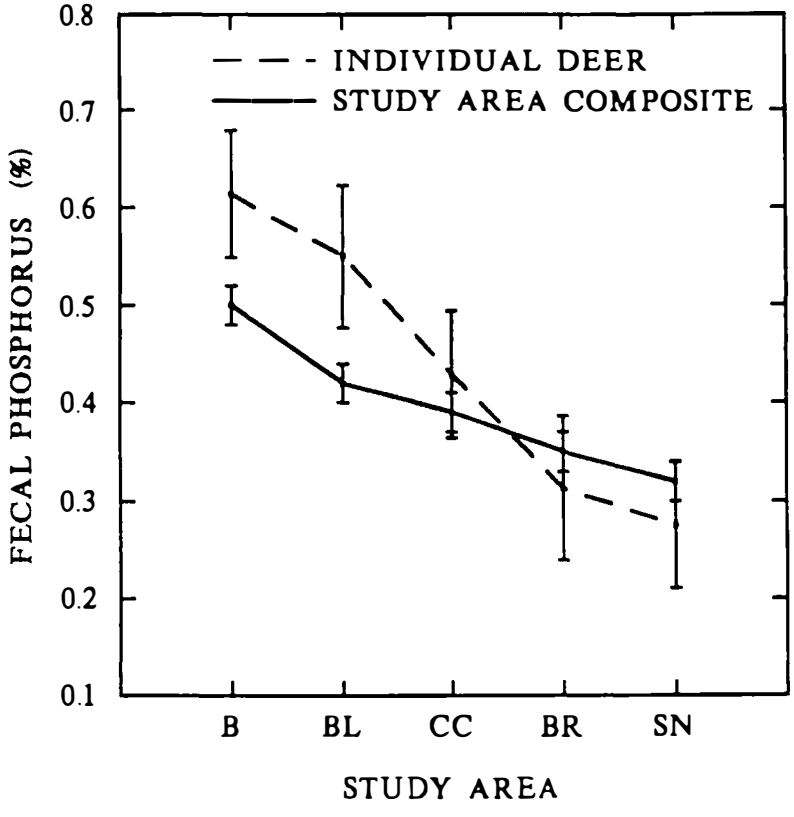

Figure 5. Average fecal phosphorus values (± one standard error) for study area composites and individual deer collected from the northern Black Hills, South Dakota, 1992.
B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

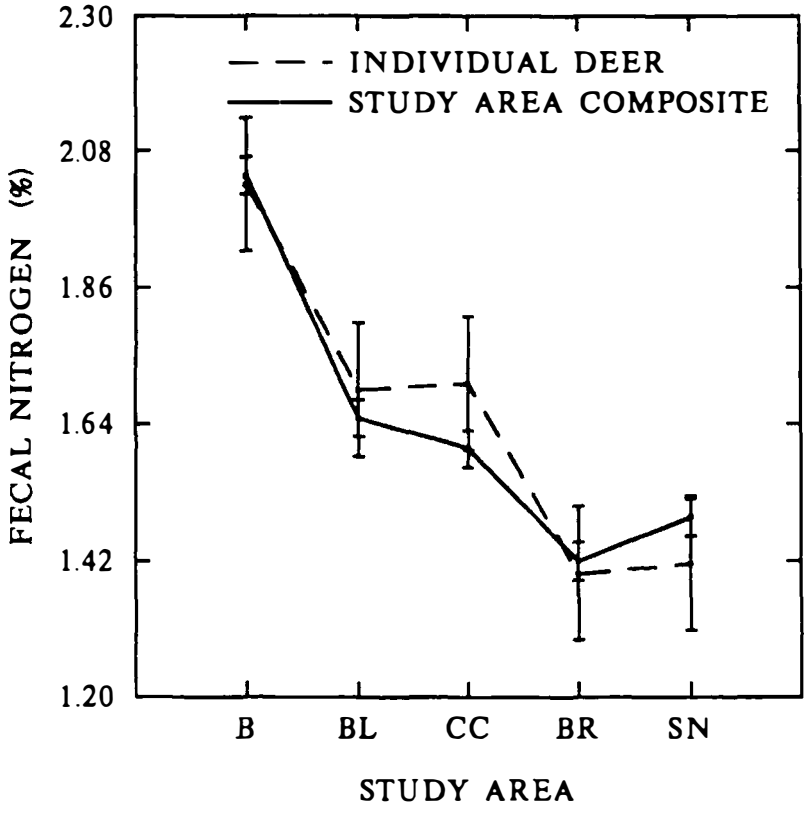

Figure 6. Average fecal nitrogen values (± one standard error) for study area composites and individual deer collected from the northern Black Hills, South Dakota, 1993.
B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

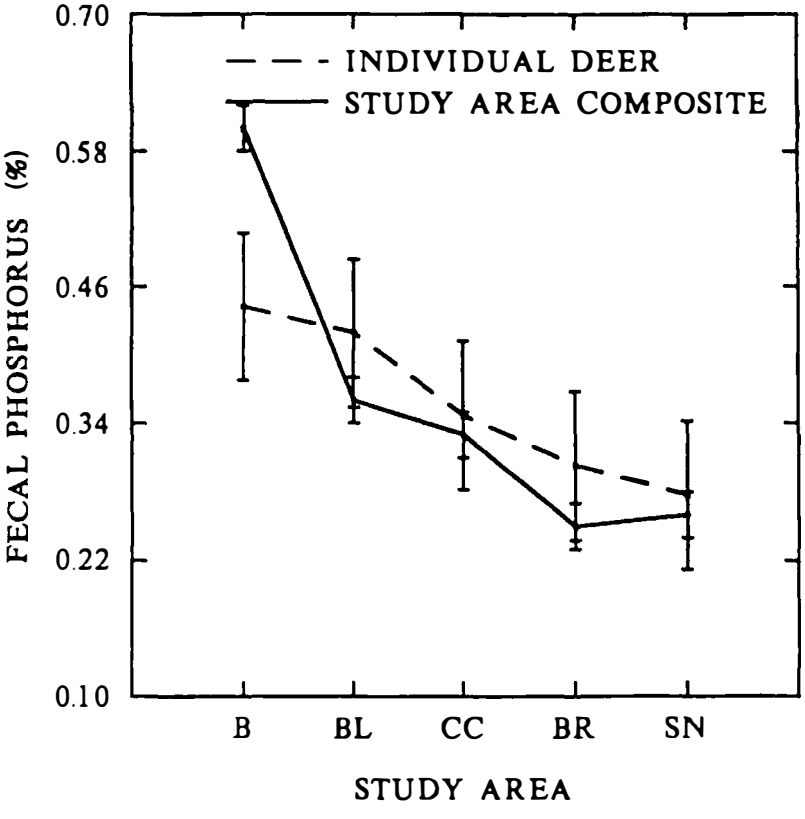

Figure 7. Average fecal phosphorus values (± one standard error) for study area composites and individual deer collected from the northern Black Hills, South Dakota, 1993.
B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

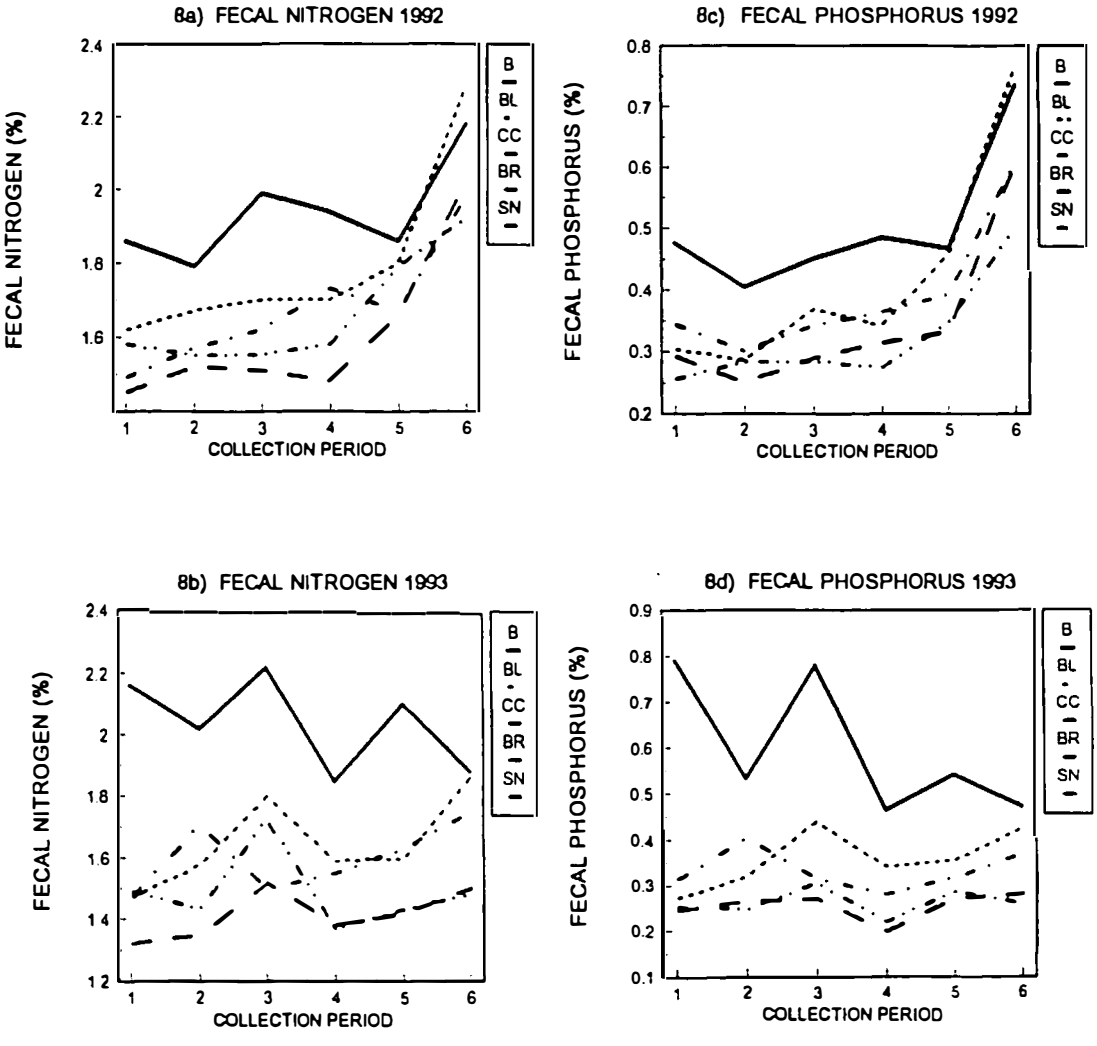

Figure 8. Temporal trends in fecal nitrogen and phosphorus concentrations determined from study area composites collected at two week intervals from 5 January to 28 March 1992 and from 3 January to 27 March 1993.

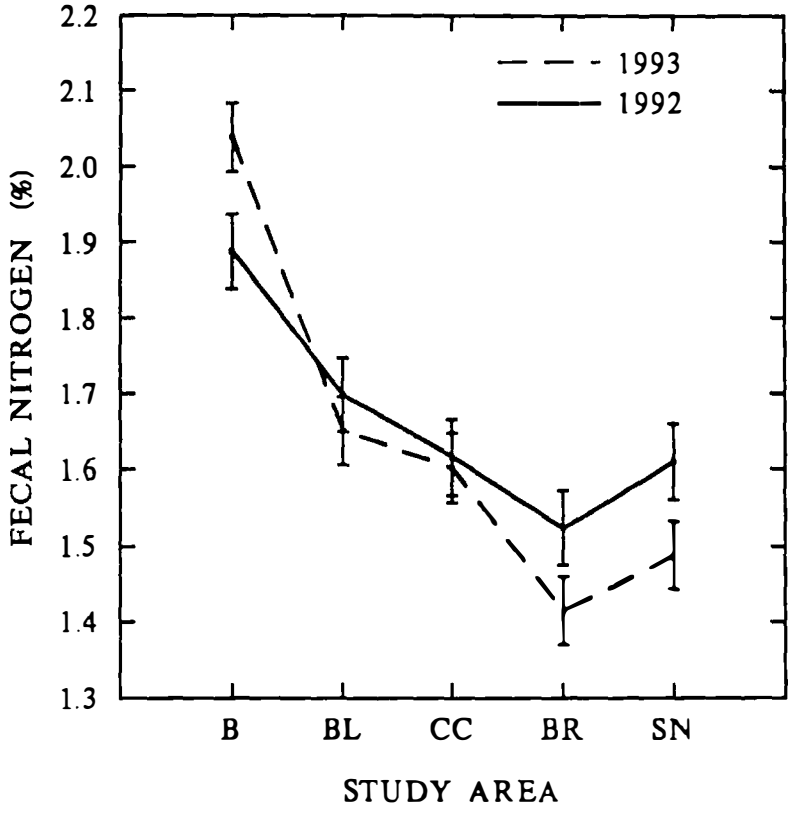

Figure 9. Average winter fecal nitrogen values (± one standard error) from winter subranges in the northern Black Hills, South Dakota, 1992 and 1993.
B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

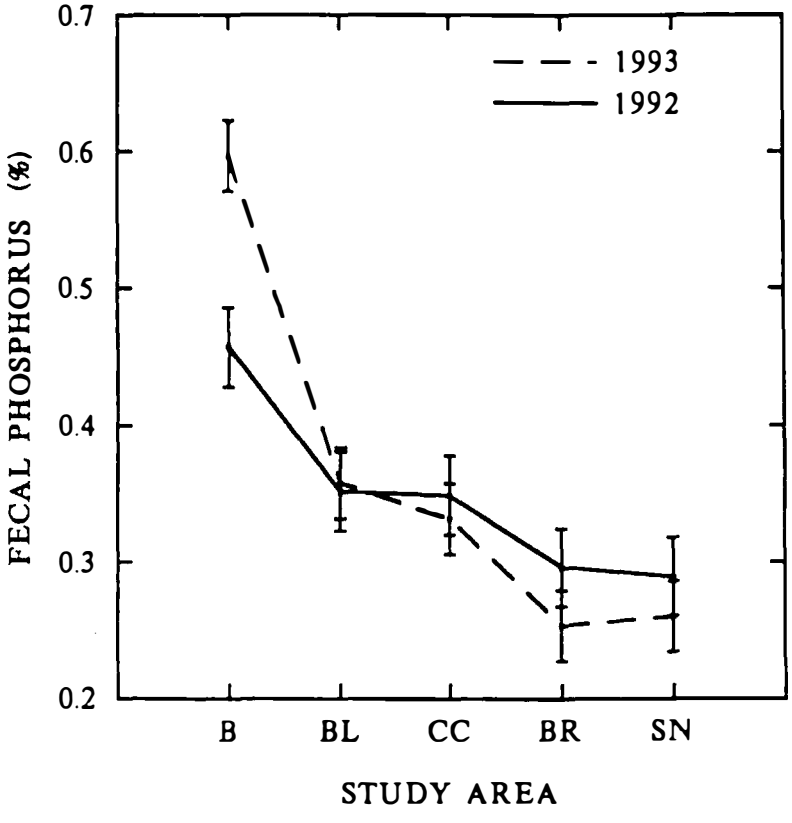

Figure 10. Average winter fecal phosphorus values (± one standard error) from winter subranges in the northern Black Hills. South Dakota. 1992 and 1993.
B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

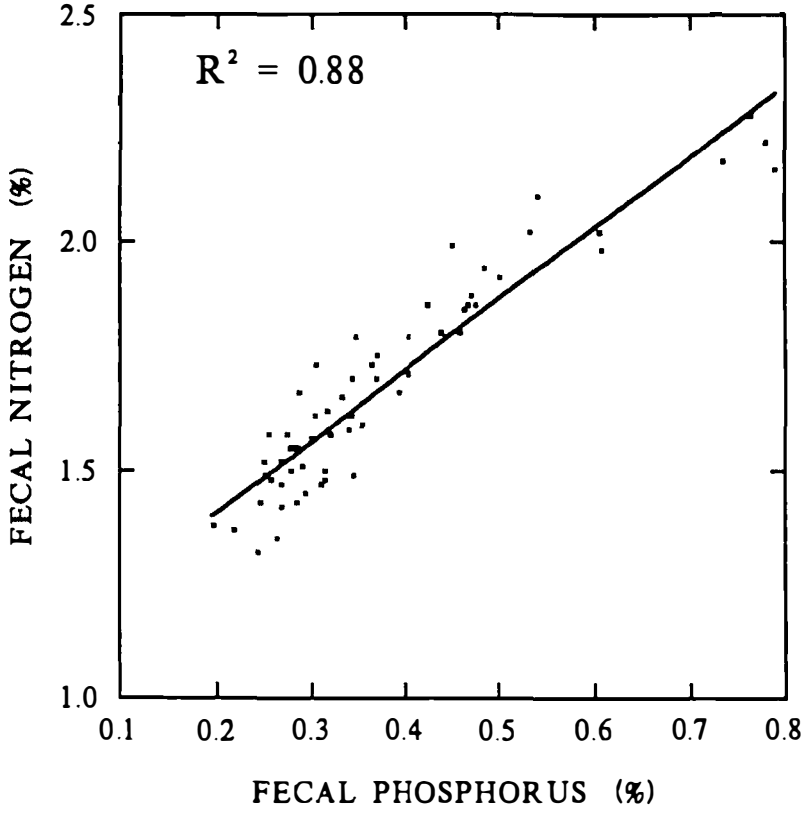

Figure 11. Correlation of fecal nitrogen and phosphorus levels determined from winter subranges in the northern Black Hills, South Dakota, January–March, 1992 and 1993.

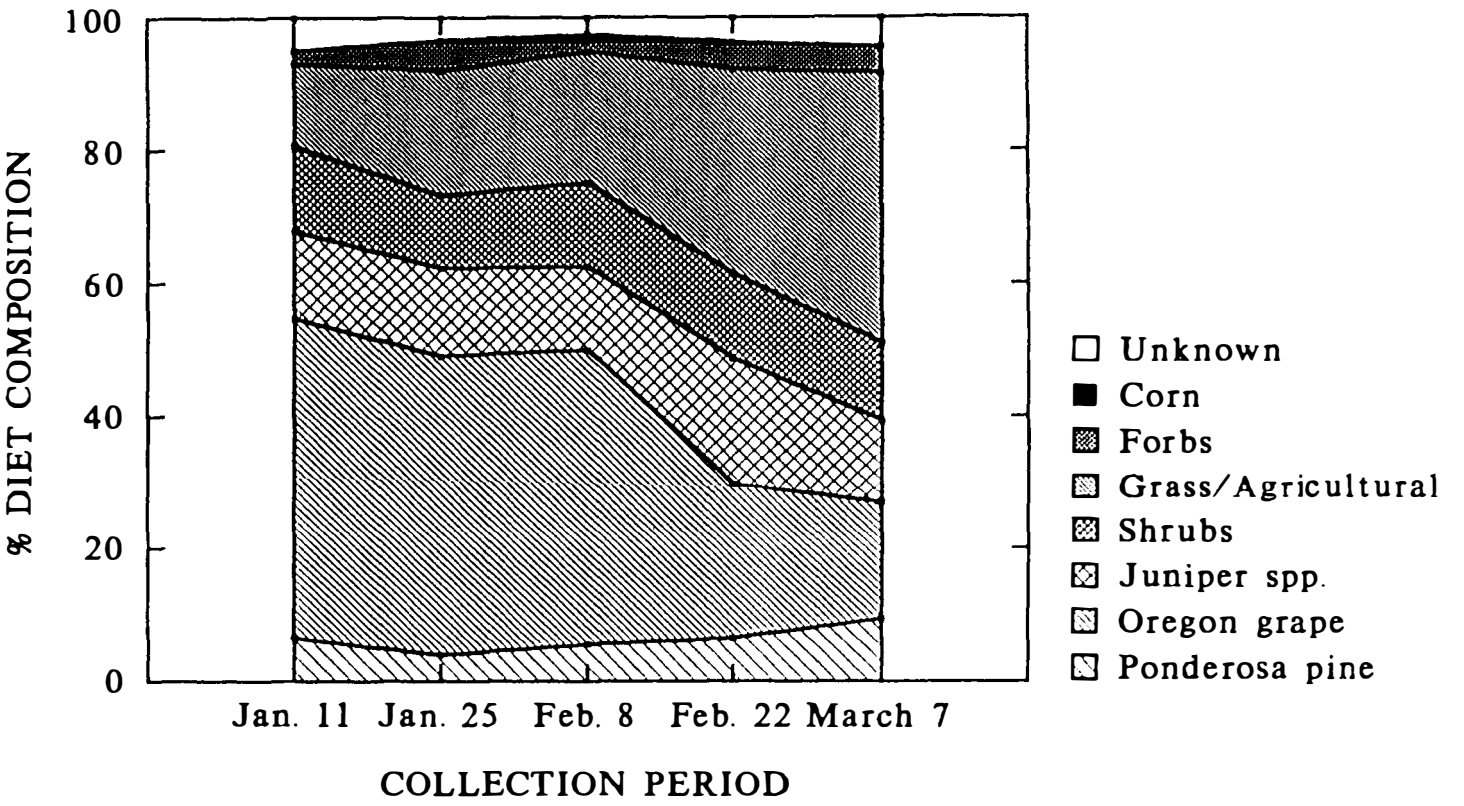

Figure 12. Intraseasonal diet composition changes of white-tailed deer in the northern Black Hills. South Dakota. January-March 1992. Collection periods are reported by the mid-point of the two week sampling interval.

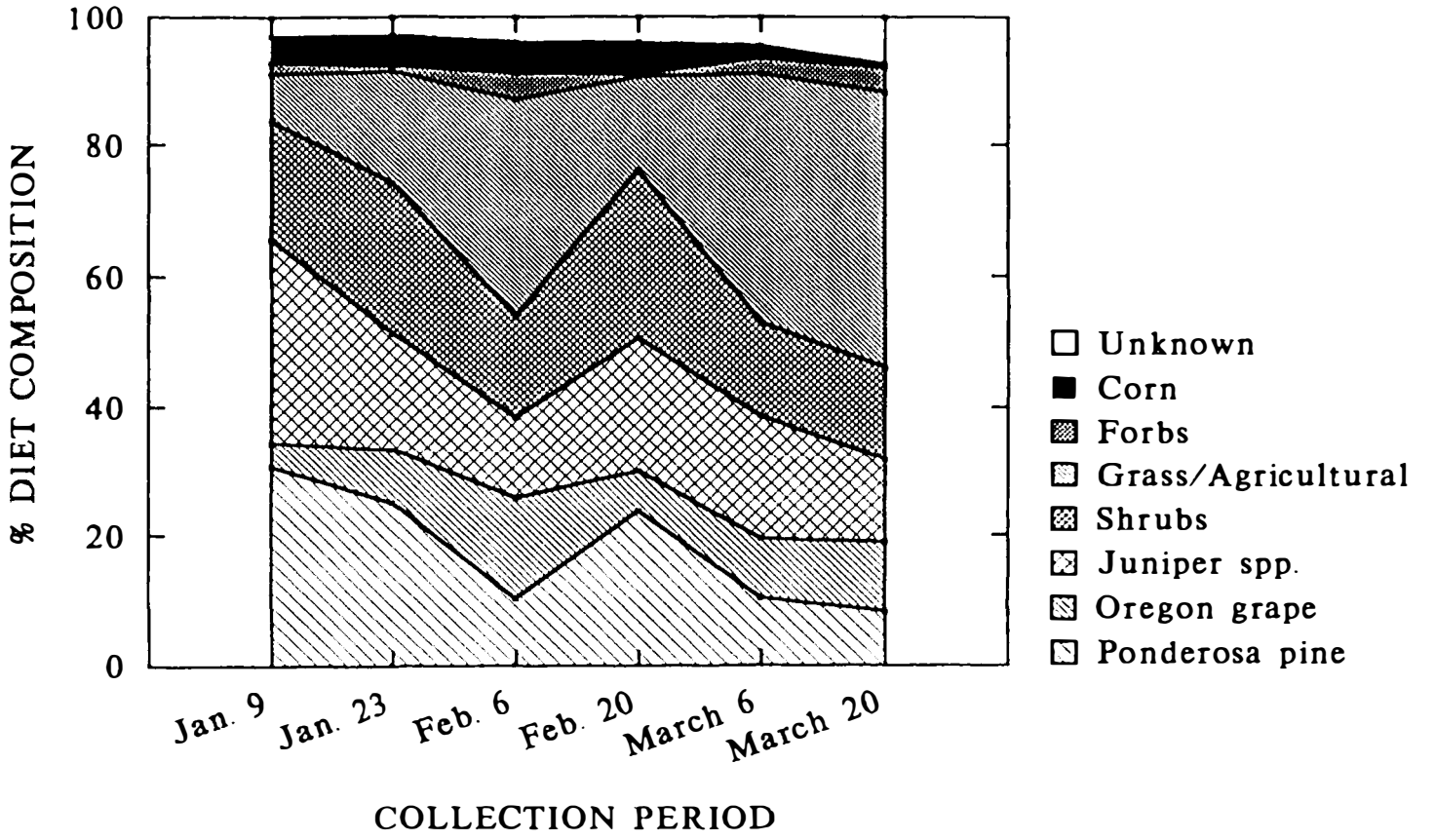

Figure 13. Intraseasonal diet composition changes of white-tailed deer in the northern Black Hills, South Dakota, January-March, 1993. Collection periods are reported by the mid-point of the two week sampling interval.

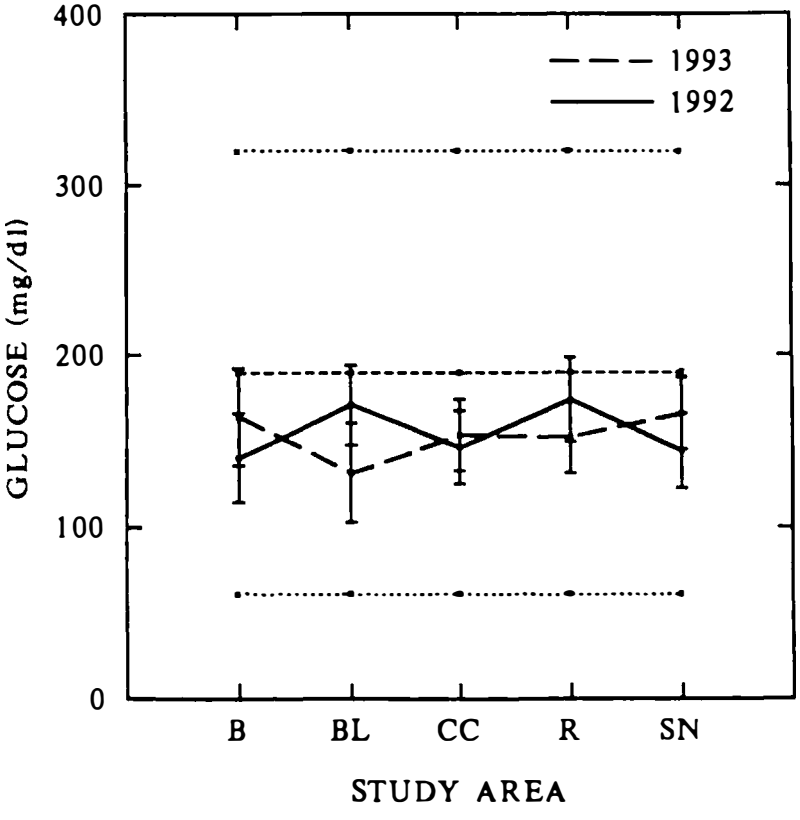

Figure 14. Average serum glucose values (± one standard error) of white-tailed deer in the northern Black Hills, South Dakota, 1992 and 1993. The horizontal lines are the minimum, maximum and mid-point reference values reported by Seal et al. (1981).
B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

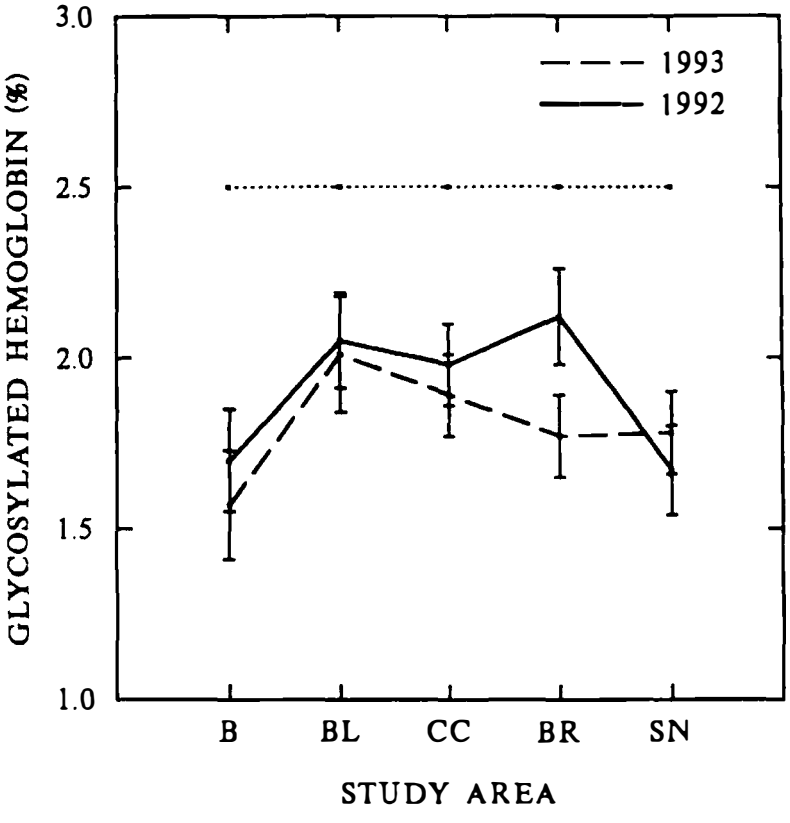

Figure 15. Average glycosylated hemoglobin values (+= one standard error) of white-tailed deer in the northern Black Hills, South Dakota, 1992 and 1993. The horizontal line is the reference value reported by Jenks et al. (1991).
B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

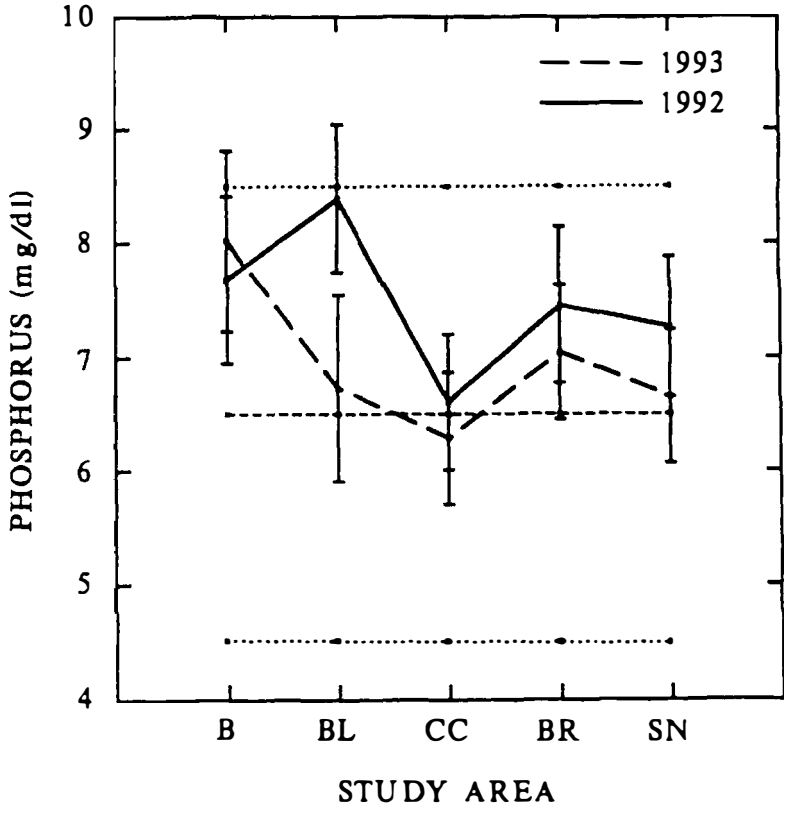

Figure 16. Average serum phosphorus values (± one standard error) of white-tailed deer in the northern Black Hills, South Dakota, 1992 and 1993. The horizontal lines are the minimum, maximum, and mid-point reference values reported by Seal et al. (1981). B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

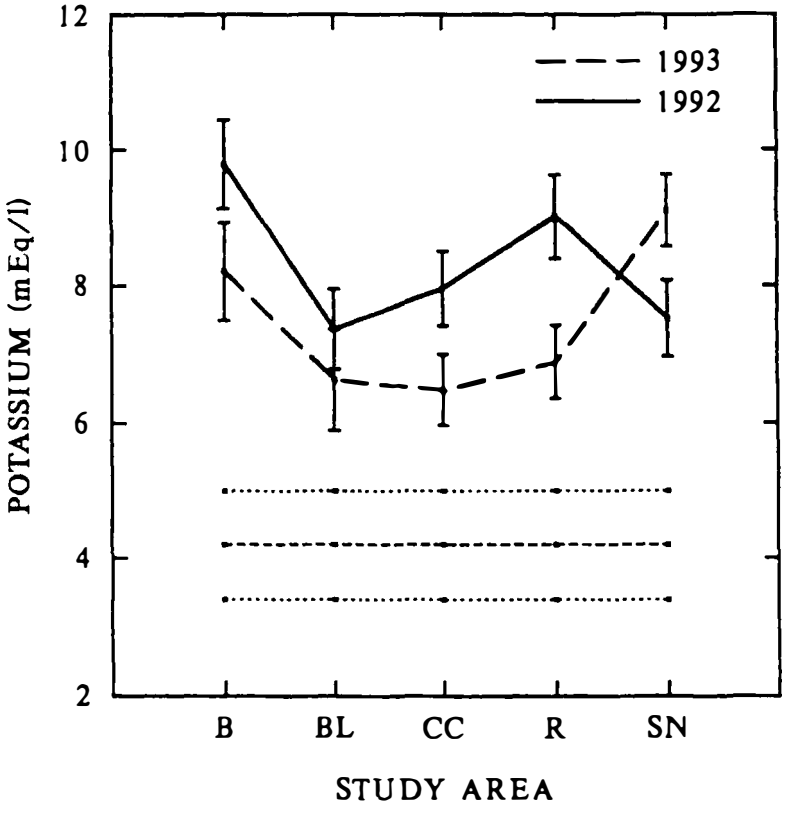

Figure 17. Average serum potassium values (± one standard error) of white-tailed deer in the northern Black Hills, South Dakota, 1992 and 1993. The horizontal lines are the minimum, maximum, and mid-point reference values reported by Seal et al. (1981). B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

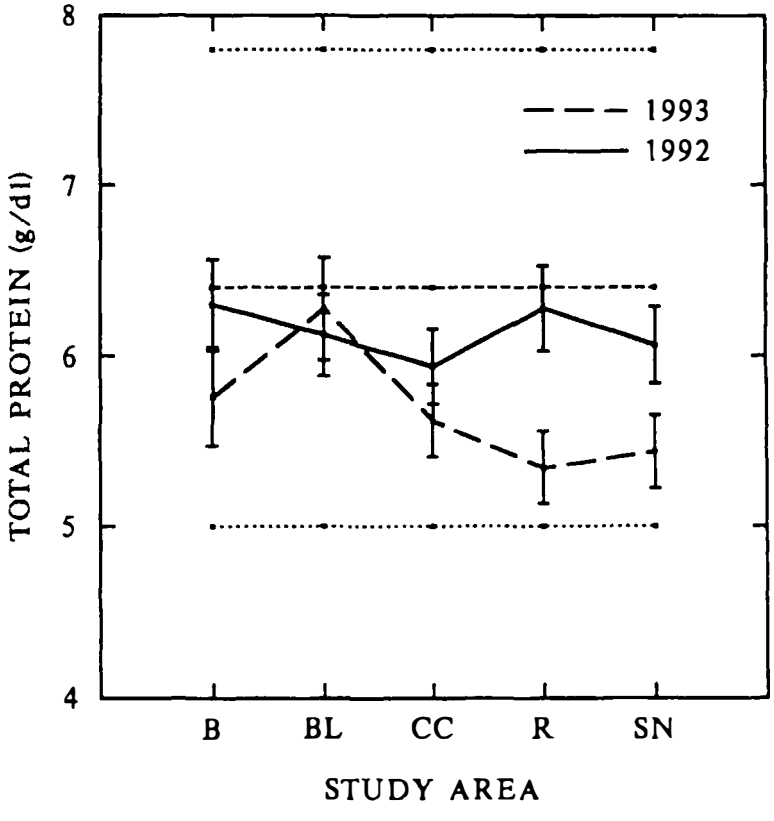

Figure 18. Average serum total protein values (± one standard error) of white-tailed deer in the northern Black Hills, South Dakota, 1992 and 1993. The horizontal lines are the minimum, maximum, and mid-point reference values reported by Seal et al. (1981). B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

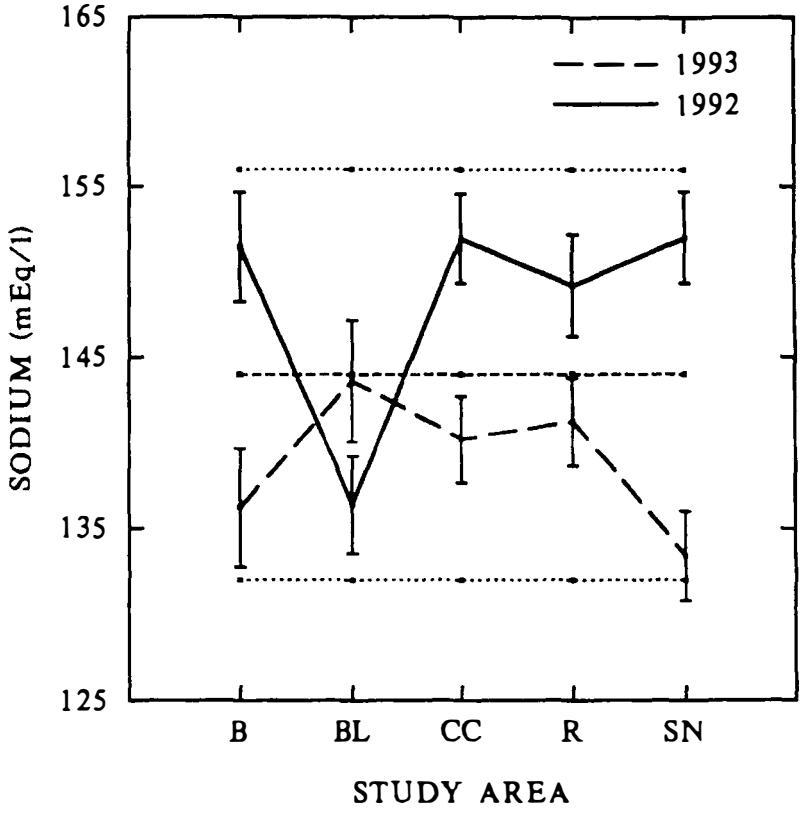

Figure 19. Average serum sodium values (± one standard error) of white-tailed deer in the northern Black Hills, South Dakota, 1992 and 1993. The horizontal lines are the minimun, maximum, and mid-point reference values reported by Seal et al. (1981). B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

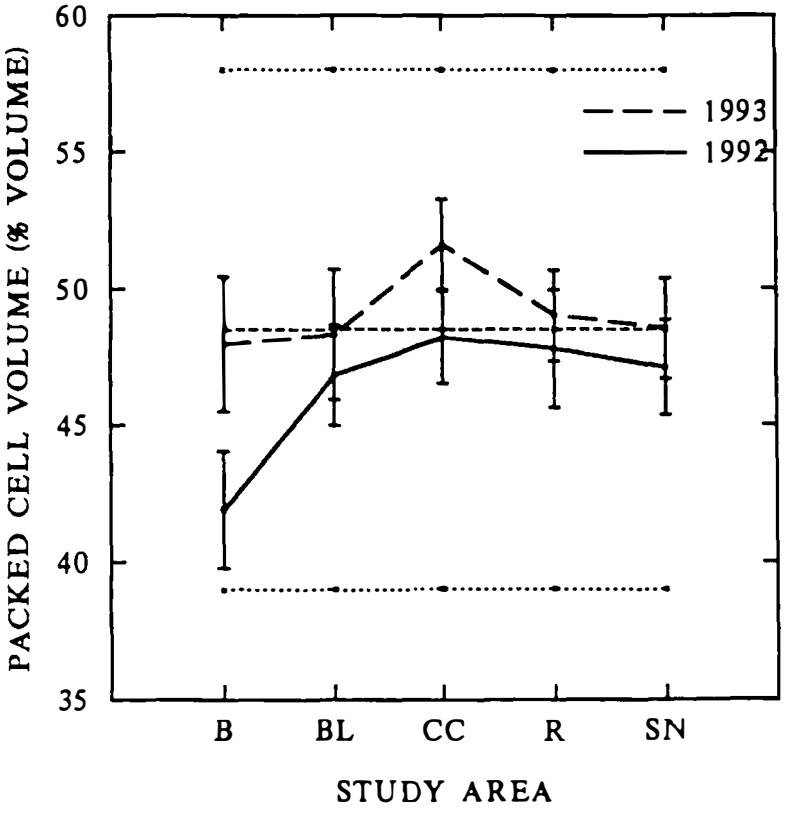

Figure 20. Average packed cell volume values (± one standard error) of white-tailed deer in the northern Black Hills, South Dakota, 1992 and 1993. The horizontal lines are the minimum, maximum, and mid-point reference values reported by Seal et al. (1981). B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

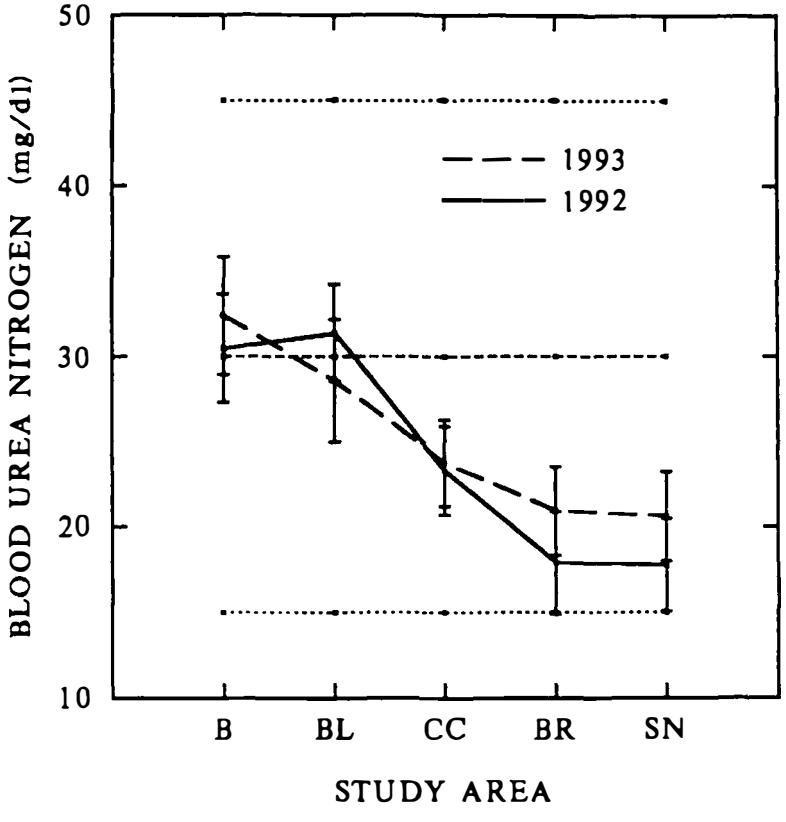

Figure 21. Average blood urea nitrogen values (± one standard error) of white-tailed deer in the northern Black Hills, South Dakota, 1992 and 1993. The horizontal lines are the minimum, maximum, and mid-point reference values reported by Seal et al. (1981).
B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

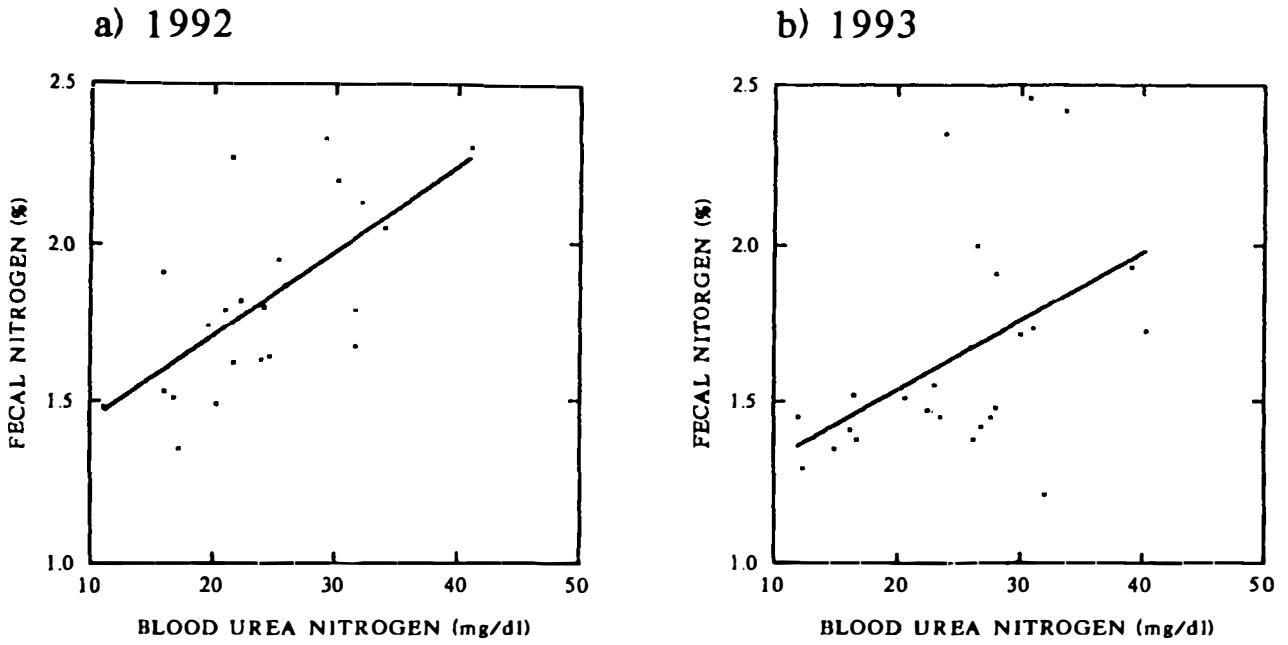

Figure 22. Correlation of fecal nitrogen and blood urea nitorgen levels of white-tailed deer in the northern Black Hills. South dakota. 1992 and 1993.

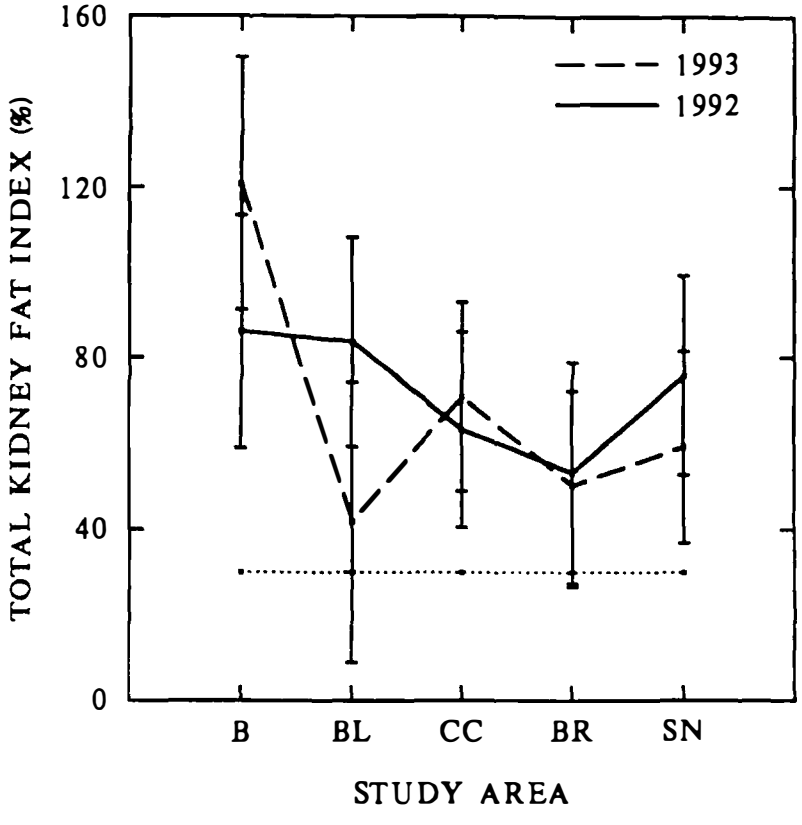

Figure 23. Average total kidney fat indices (± one standard error) of white-tailed deer in the northern Black Hills, South Dakota, 1992 and 1993. The horizontal line is the threshold below which marrow fat mobilization begins.
B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

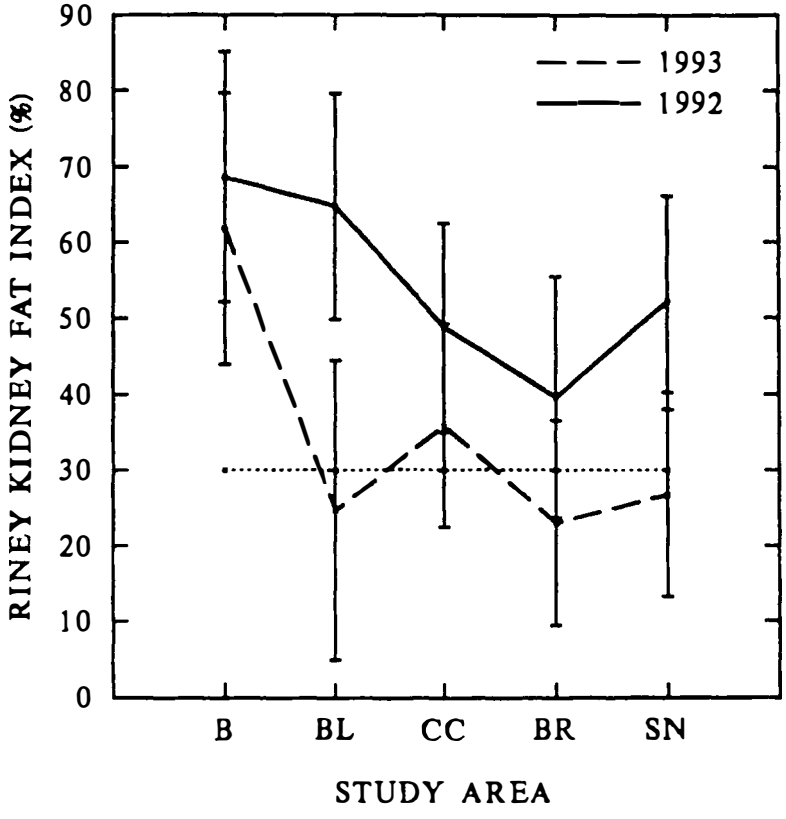

Figure 24. Average Riney kidney fat indices (± one standard error) of white-tailed deer in the northern Black Hills, South Dakota, 1992 and 1993. The horizontal line is the threshold below which marrow fat mobilization begins.
B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

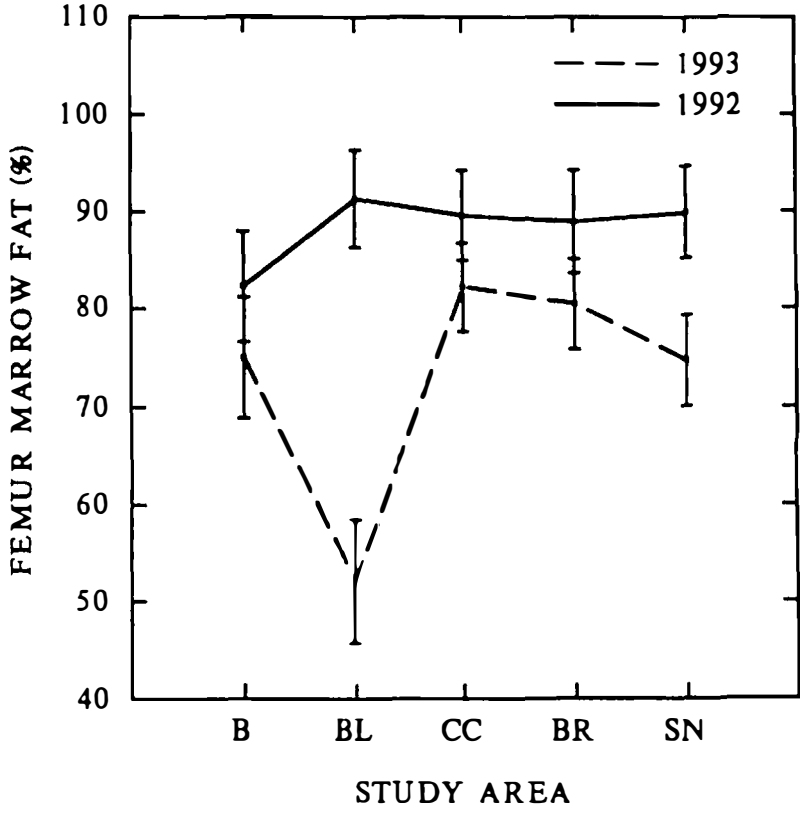

Figure 25. Average femur marrow fat values (± one standard error) of white-tailed deer in the northern Black Hills, South Dakota, 1992 and 1993. B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

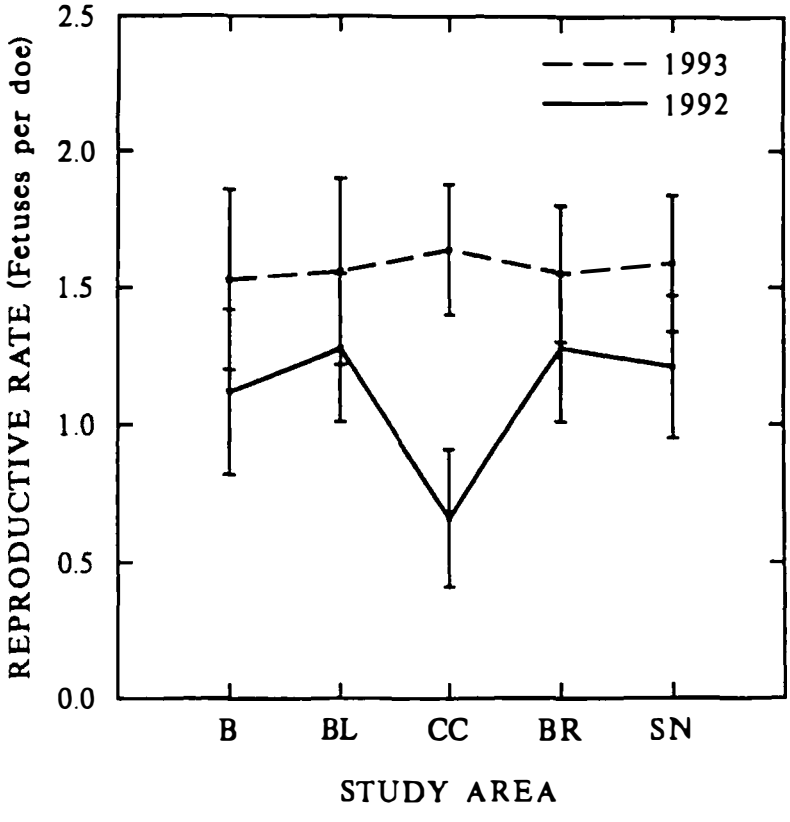

Figure 26. Average reproductive rate (± one standard error) of white-tailed deer in the northern Black Hills, South Dakota, 1992 and 1993. B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

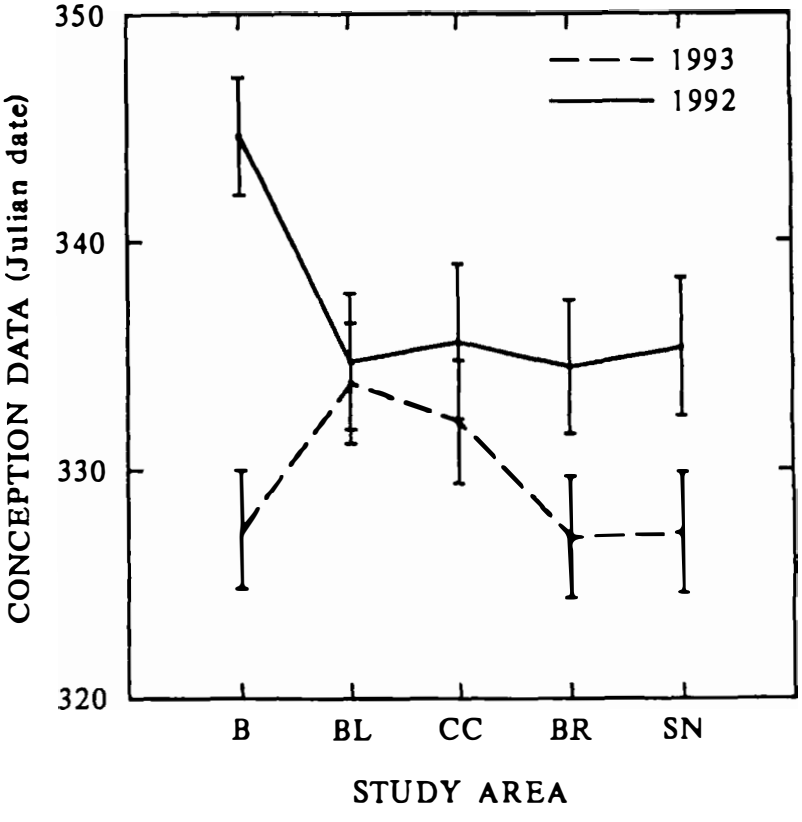

Figure 27. Average conception date (±. one standard standard error) of white-tailed deer in the northern Black Hills. South Dakota. 1992 and 1993.
B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

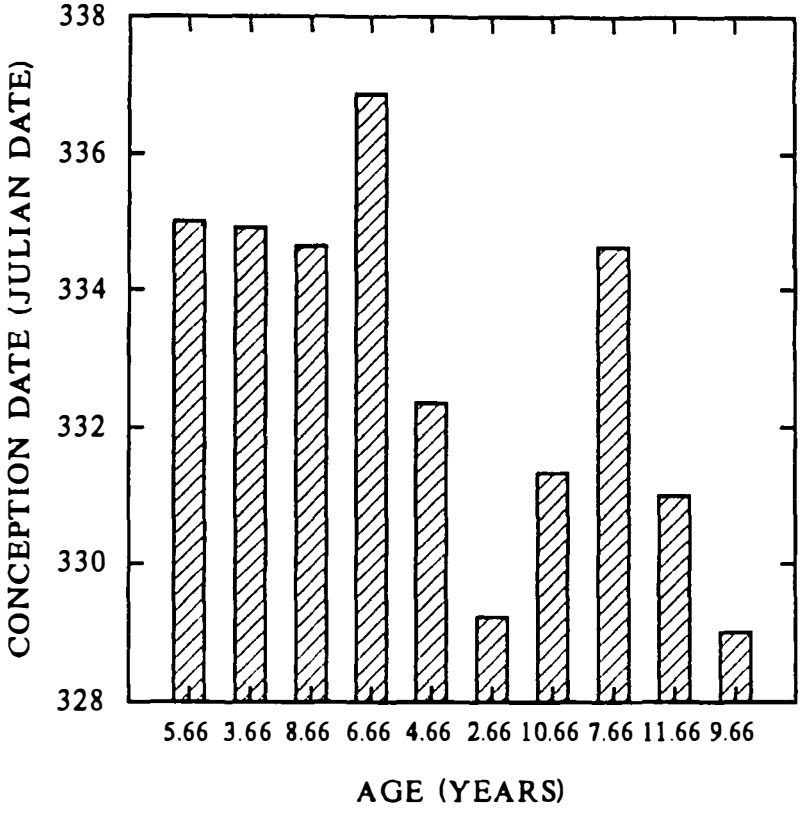

Figure 28. Average conception date by age class of white-tailed deer in the northern Black Hills. South Dakota. 1992 and 1993.

Appendix 1. Fecal nitrogen concentrations (%) from study area composites by two week collection period from winter subranges in the northern Black Hills, South Dakota, 1992 (5 January - 28 March) and 1993 (3 January - 27 March).

Collection Period	1992					1993				
	B[1]	BL	CC	BR	SN	B	BL	CC	BR	SN
1	1.86	1.62	1.49	1.45	1.58	2.16	1.47	1.47	1.32	1.49
2	1.79	1.67	1.57	1.52	1.55	2.02	1.58	1.71	1.35	1.43
3	1.99	1.70	1.62	1.51	1.55	2.22	1.80	1.50	1.52	1.73
4	1.94	1.70	1.73	1.48	1.58	1.85	1.59	1.55	1.38	1.37
5	1.86	1.80	1.67	1.66	1.79	2.10	1.60	1.63	1.42	1.43
6	2.18	2.28	1.98	2.02	1.92	1.88	1.86	1.75	1.50	1.48

[1]Study areas: B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

Appendix 2. Fecal phosphorus concentrations (%) from study area composites by two week collection period from winter subranges in the northern Black Hills, South Dakota, 1992 (5 January - 28 March) and 1993 (3 January - 27 March).

Collection Period	1992					1993				
	B[1]	BL	CC	BR	SN	B	BL	CC	BR	SN
1	0.476	0.303	0.345	0.293	0.255	0.790	0.268	0.310	0.243	0.251
2	0.404	0.286	0.300	0.250	0.283	0.533	0.320	0.404	0.263	0.246
3	0.451	0.369	0.342	0.290	0.285	0.780	0.439	0.314	0.268	0.304
4	0.485	0.343	0.364	0.314	0.274	0.464	0.340	0.278	0.196	0.218
5	0.468	0.459	0.393	0.332	0.347	0.541	0.354	0.316	0.268	0.284
6	0.735	0.764	0.607	0.605	0.501	0.471	0.425	0.370	0.278	0.257

[1]Study areas: B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.

Appendix 3. Intraseasonal dietary composition (% cover) changes among white-tailed deer in the northern Black Hills, South Dakota, 1992 (5 January - 28 March) and 1993 (3 January - 27 March).

Collection Period		1992					1993				
		B[1]	BL	CC	BR	SN	B	BL	CC	BR	SN
PIPO[2]	1	2.6	18.9	3.0	4.6	2.7	26.7	39.2	38.2	26.9	21.5
	2	2.7	7.9	2.0	2.4	4.2	13.6	37.9	28.9	25.0	19.5
	3	4.4	12.2	1.1	1.4	8.1	2.6	14.7	15.5	13.9	4.7
	4	3.8	12.3	1.8	2.4	11.2	18.9	10.1	30.5	44.0	15.3
	5	2.1	30.5	2.5	4.2	6.4	8.6	10.5	8.2	15.0	9.4
	6	6.1	17.2	2.4	7.9	9.7	1.1	13.7	7.3	13.4	5.9
BERE	1	49.6	35.5	51.7	58.2	46.5	3.5	5.4	5.2	2.0	3.1
	2	47.6	22.3	51.5	69.1	35.6	19.4	7.6	5.8	5.6	2.9
	3	34.3	31.8	38.3	67.4	51.2	9.4	18.7	21.6	21.2	6.1
	4	22.4	6.9	12.0	45.4	30.9	12.6	11.4	0.5	4.1	2.4
	5	33.7	1.7	17.0	20.1	16.3	12.3	9.4	3.9	14.7	5.0
	6	8.9	13.6	4.4	15.7	5.0	8.0	9.5	18.4	12.4	4.7

Appendix 3. Cont.

Collection Period		1992					1993				
		B[1]	BL	CC	BR	SN	B	BL	CC	BR	SN
JUSP	1	11.3	13.0	18.6	12.9	10.8	12.2	44.2	26.7	32.7	39.9
	2	12.7	19.7	16.3	10.9	6.7	11.9	17.6	24.8	16.2	20.3
	3	8.1	13.1	24.9	13.7	3.2	9.5	7.6	38.4	4.5	3.4
	4	13.8	25.3	21.3	30.7	3.1	23.2	27.0	23.0	1.1	29.4
	5	4.2	21.2	21.1	15.2	0.4	7.0	20.6	21.9	15.7	30.7
	6	20.9	4.9	33.9	9.0	0.7	3.2	13.0	22.9	11.0	13.9
SHRUB	1	14.1	9.3	2.9	14.4	22.7	11.8	7.1	19.1	28.7	23.6
	2	7.5	7.7	7.4	10.9	21.1	10.3	11.1	18.7	44.9	28.9
	3	8.7	9.5	16.9	10.7	16.9	10.4	6.6	12.6	38.6	9.4
	4	17.0	14.2	7.2	8.7	16.9	7.6	10.7	25.2	39.9	43.9
	5	12.3	7.0	12.1	19.5	7.3	10.3	8.0	10.1	19.6	23.7
	6	14.4	5.5	6.9	6.6	14.4	5.5	10.7	10.3	19.0	26.2

Appendix 3. Cont.

Collection Period		1992					1993				
		B[1]	BL	CC	BR	SN	B	BL	CC	BR	SN
GRAG	1	19.2	13.1	16.6	6.4	6.7	17.4	2.8	2.6	5.1	9.0
	2	24.5	27.7	17.9	2.3	21.2	26.1	21.8	8.5	4.5	25.6
	3	37.4	24.1	16.8	3.6	16.7	31.3	37.8	9.7	16.5	70.2
	4	34.2	31.3	50.5	6.6	30.6	15.1	33.1	10.9	7.4	6.0
	5	42.8	26.0	45.6	30.7	57.8	34.9	45.9	51.3	30.0	28.5
	6	44.6	45.9	48.8	52.7	64.5	40.2	48.5	39.5	38.6	43.9
CORN	1	0.0	0.0	0.0	0.0	0.0	18.3	0.0	3.1	0.0	0.0
	2	1.1	0.0	0.0	0.0	0.0	14.7	0.0	9.8	0.0	0.0
	3	5.5	0.0	0.0	0.0	0.0	25.2	0.0	0.0	0.0	0.0
	4	1.0	0.0	0.0	0.0	0.0	20.6	0.0	5.0	0.0	0.0
	5	0.3	0.0	0.0	0.0	0.0	10.2	0.0	0.0	0.0	0.0
	6	0.3	0.0	0.0	0.0	0.0	2.7	0.0	0.0	0.0	0.4

Appendix 3. Cont.

Collection Period		1992					1993				
		B[1]	BL	CC	BR	SN	B	BL	CC	BR	SN
FORB	1	3.1	1.2	1.9	1.5	2.1	5.1	0.3	0.2	0.7	2.5
	2	3.9	6.9	2.3	2.6	6.8	1.4	1.8	0.6	0.1	0.4
	3	0.9	1.0	2.1	2.3	2.0	6.1	5.4	0.5	3.3	5.3
	4	5.8	2.7	7.2	2.8	1.5	0.0	1.1	0.5	0.0	0.0
	5	4.5	3.0	0.8	3.2	8.3	2.2	2.8	3.4	2.6	1.1
	6	2.9	1.6	0.6	1.0	2.4	11.6	2.7	0.3	1.0	3.6
UNK	1	0.1	9.1	5.2	2.1	8.6	4.9	0.9	4.9	4.0	0.4
	2	0.1	7.9	2.7	1.8	4.5	2.6	2.4	2.9	3.8	2.3
	3	0.8	8.4	0.0	1.2	2.0	5.6	9.3	1.6	2.1	0.8
	4	1.9	7.3	0.1	3.5	5.9	2.2	6.7	4.5	3.4	2.9
	5	0.1	10.6	0.9	7.1	3.4	14.5	2.8	1.1	2.4	1.6
	6	2.0	11.2	3.0	7.1	3.4	27.6	2.0	1.4	4.5	1.4

[1]Study areas: B = Badger; BL = Burke/Larson; CC = Crow Creek; BR = Bear Ridge; SN = Sleep/Nicholas.
[2]Forage Class. PIPO = ponderosa pine; BERE = Oregon grape; JUSP = Juniper spp.; SHRUB = collective shrubs; GRAG = collective grasses and agricultural crops; CORN = corn; FORB = collective forbs; UNK = collective unknowns.

Appendix 4. Blood indices of white-tailed deer among winter subranges in the northern Black Hills, South Dakota, January-March 1992 and 1993.

	Badger		Burke/Larson		Crow Creek		Bear Ridge		Sleep/Nicholas		Northern Black Hills[1]	
Index	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Glucose (mg/dl)												
1992	140.62	25.82	171.37	22.93	146.76	21.12	174.29	24.26	144.63	21.70	155.53^{a}	9.61
1993	164.50	27.89	131.92	29.05	153.84	20.57	152.65	20.89	166.35	20.93	153.85^{a}	9.15
Area $\bar{x}^2$	142.50^{A}	19.91	157.00^{A}	17.92	152.31^{A}	14.62	163.20^{A}	15.68	156.05^{A}	14.49	------	....
Glycosylated Hemoglobin (%)												
1992	1.70	0.15	2.05	0.14	1.98	0.12	2.12	0.14	1.67	0.13	1.90^{a}	0.06
1993	1.57	0.16	2.01	0.17	1.89	0.12	1.77	0.12	1.78	0.12	1.81^{a}	0.05
Area $\bar{x}^2$	1.65^{A}	0.12	2.02^{A}	0.11	1.93^{A}	0.09	1.93^{A}	0.09	1.73^{A}	0.08	....	....
Phosphorus (mg/dl)												
1992	7.68	0.73	8.39	0.65	6.61	0.60	7.46	0.69	7.27	0.62	7.48^{a}	0.27
1993	8.02	0.79	6.73	0.82	6.29	0.58	7.05	0.59	6.66	0.59	6.94_{a}	0.25
Area $\bar{x}^2$	7.56^{A}	0.56	7.71^{A}	0.50	6.51^{A}	0.41	7.30^{A}	0.44	6.97^{A}	0.41	....	....
Potassium (mEq/l)												
1992	9.79	0.66	7.38	0.58	7.96	0.54	9.01	0.62	7.52	0.55	8.32^{a}	0.28
1993	8.21	0.71	6.64	0.74	6.49	0.52	6.90	0.53	9.10	0.53	7.46^{b}	0.26
Area $\bar{x}^2$	8.94^{A}	0.58	7.08^{A}	0.52	7.23^{A}	0.43	7.84^{A}	0.46	8.35^{A}	0.42	....	....

Appendix 4. Cont.

	Badger		Burke/Larson		Crow Creek		Bear Ridge		Sleep/Nicholas		Northern Black Hills[1]	
Index	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Total Protein (g/dl)												
1992	6.30	0.27	6.12	0.24	5.94	0.22	6.28	0.25	6.06	0.22	6.13[a]	0.10
1993	5.77	0.29	6.28	0.30	5.62	0.21	5.35	0.22	5.44	0.22	5.70[b]	0.10
Area $\bar{x}$[2]	6.23[A]	0.21	6.09[A]	0.19	5.74[A]	0.15	5.76[A]	0.17	5.75[A]	0.15	....	....
Sodium (mEq/l)[3]												
1992	151.47[a]	3.19	136.36[a]	2.83	151.95[a]	2.61	149.21[a]	2.99	152.03[a]	2.68	148.21	1.19
1993	136.21[b]	3.44	143.62[b]	3.58	140.16[b]	2.54	141.20[b]	2.57	133.40[b]	2.58	138.92	1.13
Area $\bar{x}$	143.85	2.79	139.99	2.35	146.05	1.85	145.21	1.99	142.72	1.82	.....	....
Packed Cell Volume (%)												
1992	41.92	2.14	46.82	1.84	48.22	1.70	47.80	2.16	47.10	1.74	46.26[a]	0.78
1993	47.98	2.49	48.31	2.38	51.64	1.65	49.01	1.68	48.54	1.85	49.05[b]	0.75
Area $\bar{x}$[2]	44.46[A]	1.71	47.70[A]	1.45	49.99[A]	1.17	48.23[A]	1.31	47.90[A]	1.23	....	....
Blood Urea Nitrogen[4] (mg/dl)												
1992	30.48	3.20	31.39	2.84	23.27	2.62	17.88	3.00	17.75	2.69	24.19[a]	1.14
1993	32.41	3.45	28.58	3.60	23.71	2.55	20.90	2.58	20.60	2.59	25.21[a]	1.09
Area $\bar{x}$[2]	30.21[A]	2.41	30.68[A]	2.17	23.75[B]	1.77	19.63[B]	1.90	19.22[B]	1.75	.....	....

[1] Years sharing ≥ one letter are not significantly different ($P = 0.05$).
[2] Study areas sharing ≥ one letter are not significantly different ($P = 0.05$).
[3] Within study areas years sharing ≥ one letter are not significantly different ($P = 0.05$).
[4] Supplemented deer had higher ($P = 0.022$) Blood Urea Nitrogen levels than non-supplemented deer.

Appendix 5. Morphological and physiological indices of white-tailed deer collected from winter subranges in the northern Black Hills, South Dakota, January-March, 1992 and 1993.

	Badger		Burke/Larson		Crow Creek		Bear Ridge		Sleep/Nicholas		Northern Black Hills[1]	
Index	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Spleen (g)												
1992	108.19	18.34	113.87	16.28	154.09	15.02	120.37	17.23	125.96	15.41	124.65^{a}	6.63
1993	119.33	19.81	112.96	20.64	126.47	14.61	119.63	14.82	114.46	14.86	118.61^{a}	6.33
$\bar{x}^{2}$	115.12^{A}	13.98	112.70^{A}	12.58	140.00^{A}	10.27	120.16^{A}	11.01	120.15^{A}	10.17	-----	----
Paired Adrenal Gland Weight (g)												
1992	3.91	0.44	2.90	0.46	3.22	0.37	3.74	0.43	2.73	0.38	3.32^{a}	0.18
1993	3.19	0.48	3.72	0.54	2.97	0.36	3.66	0.36	3.46	0.36	3.39^{a}	0.17
$\bar{x}^{2}$	3.67^{A}	0.36	3.28^{A}	0.36	3.06_{A}	0.27	3.66^{A}	0.29	3.10^{A}	0.26	----	----
Total Body Weight (Kg)												
1992	45.21	2.07	47.06	1.89	46.65	1.72	45.28	1.94	47.82	1.78	46.40^{a}	0.74
1993	45.69	2.25	47.72	2.35	46.96	1.71	44.36	1.65	44.80	1.71	45.91^{a}	0.71
$\bar{x}^{2}$	45.93^{A}	1.58	47.11^{A}	1.41	46.74^{A}	1.21	44.72^{A}	1.22	46.27^{A}	1.21	----	----
Eviscerated Weight (Kg)												
1992	33.06	1.54	34.74	1.40	34.75	1.28	33.46	1.44	34.66	1.32	34.15^{a}	0.55
1993	33.23	1.67	35.13	1.75	33.69	1.27	33.62	1.23	33.71	1.27	33.88^{a}	0.52
$\bar{x}^{2}$	33.32^{A}	1.16	34.84^{A}	1.03	34.21^{A}	0.89	33.54^{A}	0.89	34.15^{A}	0.89	----	----

Appendix 5. Cont.

Index	Badger		Burke/Larson		Crow Creek		Bear Ridge		Sleep/Nicholas		Northern Black Hills[1]	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Age												
1992	6.68	1.35	4.38	1.20	5.04	1.11	6.06	1.27	8.02	1.14	6.05[a]	0.50
1993	4.64	1.46	7.32	1.52	3.88	1.08	5.50	1.09	7.27	1.10	5.74[a]	0.48
$\bar{x}^2$	6.54[A]	1.06	5.40[A]	0.96	4.28[A]	0.78	5.65[A]	0.84	7.62[A]	0.77	----	----
Total Kidney Fat Index (%)												
1992	86.10	27.36	83.63	24.60	63.15	22.80	52.83	26.17	75.78	23.36	72.19[a]	10.15
1993	120.70	29.56	41.69	32.62	70.74	22.09	49.96	22.31	59.07	22.28	69.02[a]	9.85
$\bar{x}^2$	95.61[A]	21.31	67.85[A]	19.63	68.95[A]	15.77	52.93[A]	16.87	67.69[A]	15.49	----	----
Riney Kidney Fat Index (%)												
1992	68.65	16.55	64.71	14.88	48.76	13.79	39.57	15.83	52.11	14.13	54.82[a]	6.03
1993	61.79	17.88	24.69	19.73	35.85	13.36	23.02	13.50	26.76	13.48	34.71[b]	5.85
$\bar{x}^2$	60.87[A]	12.66	47.61[A]	11.66	43.42[A]	9.36	32.31[A]	10.12	39.60[A]	9.20	----	----
Femur Marrow 93 (%)												
1992	82.29	5.69	91.34	5.05	89.56	4.66	88.91	5.34	89.92	4.78	88.42[a]	2.32
1993	75.00	6.14	52.01	6.40	82.18	4.53	80.41	4.60	74.71	4.61	72.71[b]	2.21
$\bar{x}^2$	72.09[A]	4.89	75.07[A]	4.39	87.27[A]	3.58	85.95[A]	3.84	82.43[A]	3.55	----	----

Appendix 5. Cont.

Index	Badger		Burke/Larson		Crow Creek		Bear Ridge		Sleep/Nicholas		Norther Black Hills[1]	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Fetus (Number of Fetuses per doe)												
1992	1.12	0.30	1.28	0.27	0.66	0.25	1.28	0.27	1.21	0.26	1.17[a]	0.11
1993	1.53	0.33	1.56	0.34	1.64	0.24	1.55	0.25	1.59	0.25	1.58[b]	0.11
$\bar{x}$[2]	1.33[A]	0.24	1.41[A]	0.22	1.15[A]	0.18	1.56[A]	0.19	1.40[A]	0.18	----	----
Conception Date (Julian)												
1992	344.63	2.58	334.76	2.97	335.61	3.39	334.50	2.92	335.36	3.01	336.97[a]	1.31
1993	327.39	2.60	333.79	2.65	332.13	2.69	327.06	2.65	327.25	2.64	329.52[a]	1.15
$\bar{x}$[2]	336.01[A]	1.82	334.28[A]	1.93	333.87[A]	2.15	330.78[A]	2.02	331.30[A]	2.06	----	----

[1]Years sharing ≥ one letter are not significantly different ($P = 0.05$).
[2]Study areas sharing ≥ one letter are not significantly different ($P = 0.05$).